POPULAR ASTRONOMY.

He Stretcheth Out the North Over the Empty Place, and Hangeth the Earth on Nothing.

PLAINLY WORDED AND LARGELY UNTECHNICAL IN LANGUAGE. AMPLY ILLUSTRATED.

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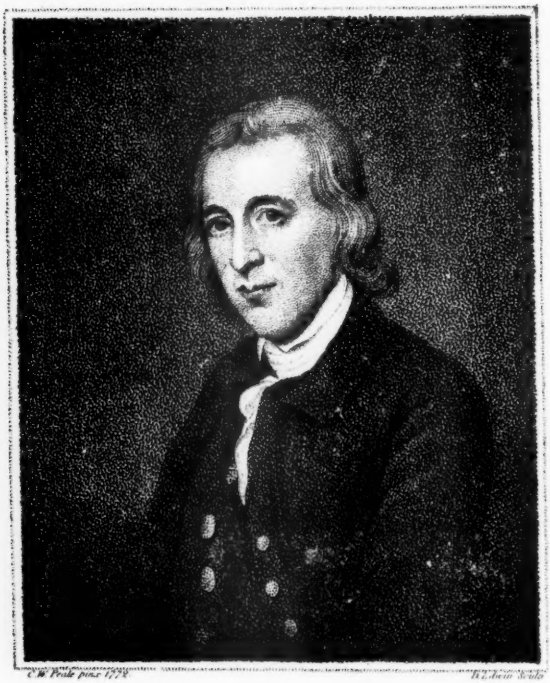
PLATE I.



David Rittenhouse

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Popular Astronomy.

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DAVID RITTENHOUSE, LL. D., F. R. S.

HERMAN S. DAVIS.

For Popular Astronomy.

In 1447 Maximilian I, the uncrowned "emperor elect" of Austria and Germany, and patron of science, art and literature, received in marriage the hand of Mary of Burgundy, daughter of Charles the Bold. Their son, Philip I, was the father of Ferdinand I, whose son, Balthaser, was crowned in 1572 Emperor of Austria, Hungary and Bohemia, and surnamed Maximilian II.

In 1591 Mathias, the second child of Maximilian II was raised with a coat of arms to the House of Knights (Hausen-Ritter or Rittershausen). A younger brother, Conradi by name, was professor of law and history in the University at Altorf, and on his son Georgius and his descendants forever was conferred at a later day the coat of arms of Mathias, who died in 1619 without heirs. Thus Georgius became Georgius Rittershausius; and this has thus become, as has not infrequently been the custom, the family name of a host of descendants.

In 1688 one of these descendants, Wilhelm Rüddinghüysen van Mülheim, a paper-maker of Amsterdam, Holland, emigrated to America and in 1690 built in partnership with William Bradford on a branch of the Wissahickon creek, near Philadelphia, the first paper-mill in this country. Here his name became Americanized to Rittenhouse. His mill property and land has remained even to the present day in possession of his direct descendants who are now numbered by the hundreds and who are represented in nearly every branch of trade and profession throughout our eastern states. Our sketch is designed as the hundredth memorial of the death of this man's great-grandson.

David Rittenhouse, whom America may best honor as her first astronomer, was born in Roxborough, Philadelphia county, Penn., on the eighth of April, 1732. The house in which he was born was built in 1707 and is still standing and used as a dwelling. When David was two years old his parents moved from Roxborough to a farm in Norriton township. Here David's youth was spent in aiding his father's agricultural pursuits and in chalking over his plow-shares and the fences with arithmetical

solutions and delineations of the constellations; for even at this early day astronomy had become his favorite study. In 1750 his father was reluctantly persuaded to let him abandon farming and adopt clock-making as a business. From this time until 1757 David applied himself unremittingly to his trade and his studies; so arduously, indeed, did he apply himself to the few books in his possession and to a stooped posture at his writing desk that he contracted "a constant heat in the pit of the stomach, affecting a space not exceeding the size of half a guinea, attended at times with much pain," and he seems to have never been free from this during the remainder of his life.

In those days when the population was sparse and community of interest rather than competition was prevalent, binding individuals together and rendering each acquainted with the other most intimately, David's reputation as a good clock- and instrument-maker and surveyor became more widely recognized than his exceeding modesty would have rendered possible in the present day. And in 1763-4 he was employed by Mr. Penn, the proprietor of Pennsylvania, to act as his surveyor in the settlement of a long-standing controversy between the Penns and Lord Baltimore concerning the division line between their possessions, Pennsylvania and Maryland. That portion of the survey which required the greatest skill was running the circle of twelve miles radius from New Castle; which circle now forms the northern boundary of Delaware. The whole task was done with such promptitude and accuracy, with instruments constructed by his own hands, as to receive grateful recognition from both litigants and larger pecuniary satisfaction than he had expected.

February 21st, 1766, he married Eleanor Colston. Two years previously had his father given up the Norriton farm to him as a homestead where he still adhered to clock-making as a trade. In 1767 we find him carrying on experiments on the compressibility of water and in constructing a metalic thermometer of the sort that has since been re-invented by Breguet within the present century. In November of this year the College of Philadelphia conferred on him the honorary degree of A. M. because of the "extraordinary progress and improvement made by a felicity of natural genius, in mechanics, mathematics, astronomy, and other liberal arts and sciences,—adorned by singular modesty and irreproachable morals." In 1769 he was employed in settling the line between the provinces of New York and New Jersey. In this work was associated with him Walter Rutherford, ancester of another famous astronomer of more recent times.

For a portion of the time when not engaged on these public matters he busied himself (1767-70) in devising what gave him among his contemporaries perhaps the greatest reputation and made his fame most popular—an orrery or planetarium. In its construction it was not his design to make a mere toy which might represent only approximately the motions of a portion of the solar system, but rather a machine of mathematical accuracy which should be useful to represent correctly the relative positions of all the planets during a period of 5,000 years both before and after the date of its construction.

The first memoir of the first volume of *Transactions of the American Philosophical Society* of Philadelphia is a description of this orrery as communicated by him shortly before its completion. He thus speaks of it:

> From the centre arises an axis, to support a gilded brass ball, intended to represent the Sun. Round this ball move others, made of brass or ivory, to represent the planets: They are to move in elliptical orbits, having the central ball in one focus; and their motions to be sometimes swifter and sometimes slower, as nearly according to the true law of an equable description of areas as is possible, without too great a complication of wheel-work. The orbit of each planet is kew ise to be properly inclined to those of the others; and their aphelia and nodes justly placed and their velocities so accurately adjusted, as not to differ sensibly from the tables of astronomy in some thousands of years. * * * When the machine is put in motion, by the turning of a winch, there are three indexes, which point out the hour of the day, the day of the month and the year, (according to the Julian account) answering to that situation of the heavenly bodies which it then represented; and so continually, for a period of 5,000 years, either forward or backward. * * *
>
> (One of the three faces) represents and exhibits all the appearances of Jupiter, and his satellites, their eclipses, transits and inclinations: Likewise all the appearances of Saturn, with his ring and satellites. And (another face) represents all the phænomina of the Moon, particularly the exact time, quantity, and duration of her eclipses, and those of the Sun, occasioned by her interposition; with a most curious contrivance for exhibiting the appearance of a solar eclipse at any particular place on the Earth: Likewise the true place of the Moon in the signs, with her latitude, and the place of her apogee and nodes, the Sun's declination, equation of time, etc. It must be understood that all these motions are to correspond exactly with the celestial motions, and not to differ some degrees from the truth, as is common in orreries. * * * The diurnal motions of such planets as have been discovered to revolve on their own axes, are likewise to be properly represented; both with regard to the times, and the situation of their poles.

This elaborate piece of delicate mechanism was completed in 1770 and excited at once the wonder and curiosity of all his acquaintances. Thomas Jefferson wrote of it that it is "a machine far surpassing in ingenuity of contrivance, accuracy, and utility anything of the kind ever before constructed. He has not indeed

made a world, but has by imitation approached nearer its Maker than any man who has lived from the creation to this day." Even the poetaster has attempted to immortalize its originator by measured rhyme:

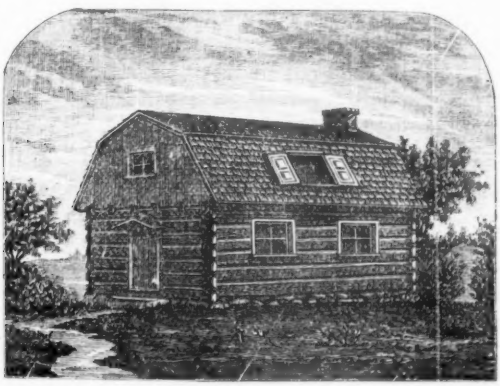
> See the sage Rittenhouse, with ardent eye,
> Lift the long tube and pierce the starry sky;
> Clear in his view the circling systems roll,
> And broader splendours gild the central pole.
> He marks what laws the eccentric wanderers bind,
> Copies Creation in his forming mind,
> And bids, beneath his hand, in semblance rise,
> With mimic orbs, the labours of the skies.

Other writers gave it unstinted praise and from at that time far-off England he received an invitation to carry it there for exhibition and deliver therewith a series of lectures on astronomy. This invitation was not accepted and within a month of its completion the orrery was purchased for the College of New Jersey by Dr. Witherspoon, the president. The sum paid was £300. No sooner had this sale become known to Dr. Smith, provost of the College of Philadelphia and Rittenhouse's intimate friend, than he vented his mortification at the loss of so rare a treasure for his own college in a letter from which we quote: "I thought I could depend, as much as on anything under the Sun, that after Mr. Rittenhouse knew my intentions about it, he would not have listened to any proposal for disposing of it, without advising me, and giving our College the first opportunity to purchase. I think Mr. Rittenhouse was never so little *himself*, as to suffer himself to be taken off his guard on this occasion. This province is willing to honor him as her *own*; and believe me, many of his friends wondered at the newspaper article; and regretted that he should think so little of his *noble* invention, as to consent to let it go to a *village*." The rivalry between the Colleges was keen, but Rittenhouse honorably delivered the goods sold and Princeton University still possesses the coveted wheel-works—not by any means, however, so proud of them now as a century ago; for within the last half decade they have been rescued from the rubbish heap of a dusty store-room; accidentally discovered among the accumulations of years by workmen making alterations in one of the buildings.

For this orrery to have escaped injury from the rough treatment of ignorant soldiery quartered in Nassau Hall seems but to have permitted it to out-live its usefulness and its glory. Undoubtedly its highest value now is to reflect one's thoughts to the

past and on its face to show the history of its by-gone lustre. Although, in accordance with the tastes of men of that age and in this new, developing country, where determining the azimuth of a line was regarded as a high application of practical astronomy and the computations incident to a boundry survey a consummate proof of the highest order of mathematical ability, this orrery was rightly esteemed a most admirable piece of mechanism to imitate celestial phenomena; and it does to that degree, indeed, reflect high credit upon the originality, patience and ingenuity of its self-taught constructor—the plain farmer lad of royal lineage.

Yet we would not at the present day place David Rittenhouse beyond comparison with every other mathematician and astronomer, save Newton, as some of his contemporaries did; when we bear in mind that at this very time, among others of note, Clairaut, Euler and La Grange were astonishing Europe with their mathematics, Herschel with his discoveries, and Laplace was beginning that work which has immortalized his name. Nor would we imagine ourselves doing justice to the subject of our sketch if we should endeavor to perpetuate this popular craze and admiration for a machine so useless in modern times, even though so beautifully constructed; notwithstanding that he himself without doubt thought it his most valuable contribution to the science he loved. David Rittenhouse gave a better offering to Urania than this.



Observatory built by Rittenhouse at Norriton, Penn., 1768-9.

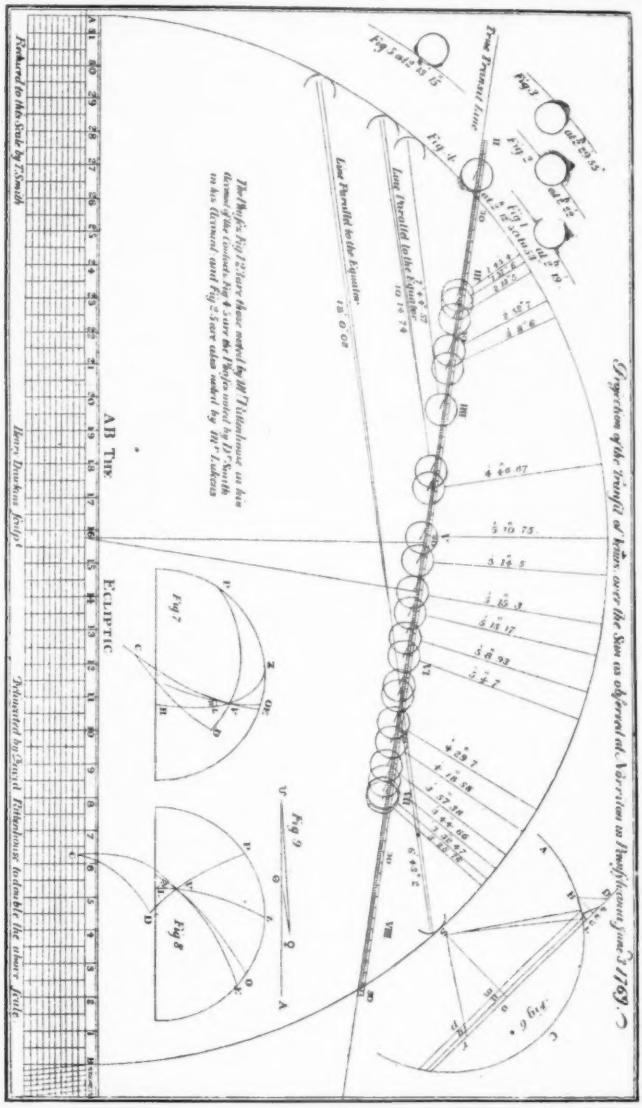
On June 3, 1769, occurred a transit of Venus. Preparatory to making observations of this Rittenhouse had erected at his

Norriton homestead a log-observatory and had constructed an equal-altitude instrument, a transit telescope and a clock. For months previous to the eventful day he made many time determinations for clock-rate and left no duty of even the smallest importance unperformed. He was urged on and aided by the American Philosophical Society of Philadelphia, of which he was a prominent member, and which had confided to him entire charge of this one of the three selected stations. Dr. Smith, provost of the College of Philadelphia, and Mr. Lukens, surveyor-general of Pennsylvania, aided him in the observations. Their detailed report was communicated to the Society by Dr. Smith June 20th, following. In this report he gives excuse for not taking part in the preparations on the ground that "we had entrusted them to a gentleman on the spot, who had joined to a complete skill in mechanics, so extensive an astronomical and mathematical knowledge, that the use, management, and even the construction of the necessary apparatus, were perfectly familiar to him."

We need not enter into the particulars of that day's breathless expectancy and glorious satisfaction of predictions fulfilled. Those who wish to do so may read them in *Transactions of the American Philosophical Society* (Vol. I. pp. 8-133); and very interesting reading they are, too. The scientific worth of these observations may be briefly stated in Professor Newcomb's words: "I conclude that Rittenhouse did not observe any definite phase. It is, I believe, an historic fact that he was nearly overcome by the excitement of the moment." But in an estimate of the character of Rittenhouse his work on that day has an importance that is not to be judged entirely by its contribution to astronomy of precision. It must be remembered that he was a self-taught amateur—a pioneer on this side of the Atlantic; that his preparations were unusually well planned and executed; that he showed a nicer appreciation of the difficulties to be overcome—a truer scientific instinct—than any other observer in this country. One who reads the full report will certainly be impressed with these characteristics in contrast with the efforts of others in various parts of the Colonies. His computations of the times of contact were very accurate and his projection of the transit superbly drawn.

On Nov. 9th of this same year he observed a transit of Mercury, record of which is also in the first volume of the *Transactions*. In June and July, 1770, with a sextant he observed Lexell's comet and computed its orbit on the supposition of its parabolic form. As his observations extended over only six days and great

precision was not attempted his computed and observed places agree with tolerable accuracy, especially in view of so erroneous a


Projection of the Transit of Venus over the Sun as observed at Norriton in Pensylvania June 3d 1769.
Fig 1
Fig 2
Fig 3
Fig 4
True Perpendicular Line
Line Parallel to the Equator
Line Parallel to the Ecliptic
Fig 5
Fig 6
Fig 7
Fig 8
Fig 9
ECLIPTIC
AB The
Reduced to this Scale by P. Smith
Engraved by David Rittenhouse Instrument Maker
Transit of Venus in 1769, as observed at Norriton, Penn.

supposition. In his communication to the society we find the

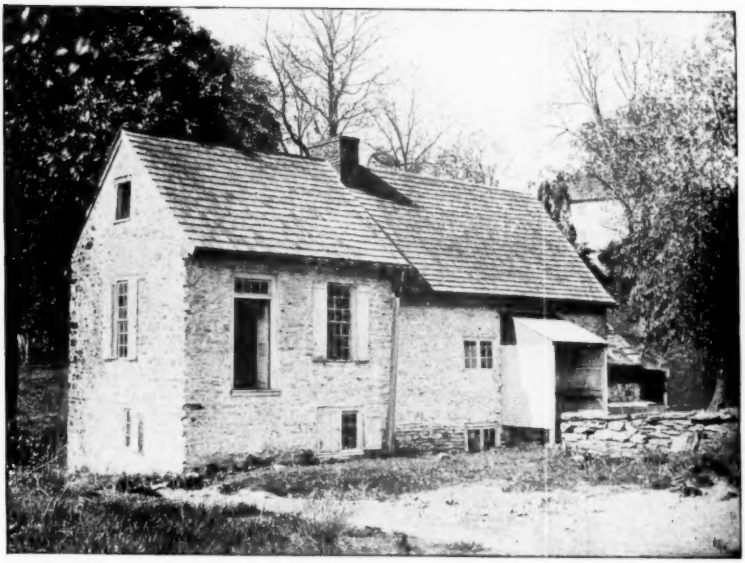
curious remark: "perhaps, if the apparent distance of the nucleus from some fixed star near which it passed, had been measured with a micrometer, at different places on the earth conveniently situated, the Sun's parallax might, by this means, have been determined nearer than we can ever hope for, by any other method."

In the autumn of 1770 Rittenhouse took up his abode in Philadelphia. Here he was thrown into more intimate association with Franklin, Smith, Ewing and other foremost men in science and in politics. He also took a more active part in the proceedings of the Philosophical Society; was elected first its secretary, then its vice-president, and much later, at Franklin's death, its president (1791).

So early as 1771 was begun to be felt the depression in business and science arising from the impending war. The fact that a period of fifteen years elapsed between the publication of the first and the second volumes of the *Transactions* is ample testimony to the deplorable effects of that depression upon the intellectual activity of the community. There was an interval of about ten years between the latest of Rittenhouse's communications printed in volume one and the earliest in volume two, yet he was by no means idle. His activity during this interval and later, was displayed by all sorts of commissions, such as 'to make the Schuylkill navigable' (1773), 'to run the boundary line between Pennsylvania and New York' (1774), 'to settle the boundary between Virginia and Pennsylvania' (1779–83), 'to determine the boundary between New York and Mass.' (1785–'87), 'to open a canal between the Schuylkill and Delaware rivers' (1792), etc. In addition to the duties thus imposed he was a member of the General Assembly of Pennsylvania as a burgess of Philadelphia (1776), a Justice of the Peace (Sept. 1776), the State Treasurer (1777–'89), one of twelve on the Council of Safety—the only body in this country ever endowed by the people with *absolute* power of life and death (1777), Trustee of the Loan Office (1780–'90), Director of the Mint (1792–95), etc.

Yet amid all this we notice that he ever found opportunity to indulge in those astronomical pursuits for which he early displayed an aptitude—regarding them as relaxations from the arduous duties which he had assumed from consideration of patriotism. Among the least important of these we may mention: his observations of the transit of Mercury of November, 1776; of the solar eclipses of January, 1777, and June, 1778; of the newly discovered Uranus; and of a comet discovered by himself 11th of January,

PLATE II.



The House in which David Rittenhouse was born, April 8, 1732.

The Rittenhouse Homestead, near Norriton, Penn.

1793. To these may be added some miscellaneous experiments in optics also the invention of a wooden hygrometer and at least two forms of compensating pendulums as well as all the calculations for *Father Abraham's Pocket-Almanack*, a few newspaper articles to refute certain of the Cartesian theories, and the computation of comet orbits "from three observations."

His life was a busy one in spite of his persistently poor health; and for the amount of work that he was able to do he owes much to the business ability of his second wife, whom he married in 1772. She was competent to manage admirably all the affairs of the Loan Office and of the State treasuryship, thus permitting his lengthy absences from home to adjust the boundaries of the States.

In December, 1779, David Rittenhouse was elected Professor of Astronomy at the College of Philadelphia, with a salary of £300 and two months later received the vice-provostship with the additional salary of £100. The acceptance of the first position formally removed him from the ranks of amateurism. The same result was nearly accomplished four years earlier when there was (March 1775) before the legislature of his native State a bill, the object of which was to provide for the appointment and salary of a public astronomer and the erection of an Observatory. It was the universal opinion that Rittenhouse was to be this public astronomer though not by name designated in the bill. Thus early was one province at least on the point of making an open demonstration of its interest in science; but, alas! too soon was heard the roar of cannon at Concord, the ominous call to more mundane duties on the part of the people's Assemblies. The bill was neglected. This effort of his friends failed. We are not aware to what extent he actually performed his professorial duties at the college; it is highly probable that he did more than merely draw his salary, for he had a very nice sense of honor, especially in financial matters: when its treasurer, he refused to invest in loans of the State; and when compelled as director of the mint to pay certain exorbitant bills for that institution he had them charged against his own salary.

In the latter part of his life he was the recipient of many honors. In 1782 he was elected Fellow of the Academy of Arts and Sciences of Boston; in 1784 the college of William and Mary gave him a second A. M., probably because of the influence of Dr. James Madison, its president and his constant correspondent and friend. In 1789 the College of New Jersey conferred on him the degree of Doctor of Laws; and in 1795 he was admitted to membership in the Royal Society of London.

David Rittenhouse was indeed America's pioneer astronomer, yet no *great* principle either theoretical or practical was originated by him. His career was not that of a genius of exceeding power; he had the fortune to live in the prime of his country's life; to love a rare science, and by a genial disposition to impress his personality upon his acquaintances. To most of the knowledge that he acquired from reading he was able, by a quickness of perception of its needs, to add some slight improvement; but even with these additions the result often lacked an European finish; and much of his fame among his fellow-countrymen was due more to their remoteness from the old continent and their consequent ignorance of the progress of Newton's followers and Bradley's contemporaries, than to the substantial accomplishment of the results that we judge ought to have attended the enthusiasm and insight which Rittenhouse seems really to have possessed. Several writers have attributed to him even an independent discovery of fluxions, but dates render one suspicious and after a careful examination of all his published papers, we fail to see that they present the slightest evidence of such discovery—or that they even show signs that he was intimately acquainted with its principles from a borrowed source. Problems which require but slight knowledge of the calculus were treated by him algebraically and inductively and were generalized by analogy, rather than deduced from simple principles at that time well understood in the Old World.

Rittenhouse was more of a mechanician than a mathematician, and for two things he deserves the astronomers' special gratitude. Grant in his *History of Physical Astronomy* (p. 506) says: "We may remark . . . as an earnest of what may be expected from the future exertions of our trans-atlantic brethren, that to an American philosopher practical astronomy is indebted for the beautiful invention of the collimating telescope." He did not give the name of that philosopher: mark it on the margin of your *Grant* because for this one thing even if for no other the name of David Rittenhouse deserves to be recorded. As for many years had been the custom, Rittenhouse used for the meridian mark for his transit instrument a dot on a post many feet from the Observatory. But this was in the heart of a growing city and soon the building of adjacent houses cut off the view, rendering his 1200-foot mark useless. In this dilemma, to use his own words, written Nov., 1785:

> I fastened the object glass of a thirty-six feet telescope firmly to the wall which supports the transit instrument, opposite to and as near as convenient to

the object glass of the transit when brought to a horizontal situation. In the focus of the thirty-six feet object glass I screwed fast a piece of brass to a block of marble, supported by a brick pillar built on a good foundation, for this purpose, in my garden. On this piece of brass are several black concentric circles; the rest of the plate is silvered. The diverging rays of light which proceed from every point in this circle after passing through the thirty-six feet glass become parallel and entering the transit instrument an image of the plate and its circles is formed in the same place where the images of stars or the most distant objects are formed. The circles are therefore distinctly seen through the transit, and being placed in the same meridian with the centre of the thirty-six feet glass, the innermost circle, about the size of a brevier o, serves for a meridian mark, to the centre whereof the cross-hair of the transit may be nicely adjusted. This mark is in several respects preferable to one placed in the common way. It is entirely free from parallax, which the other cannot be, unless placed at a very great distance, when glasses of great magnifying powers are used. It is not sensibly affected by the undulation of the air, which very often render it impossible to set the transit accurately to a meridian mark. And it can be illuminated at night without difficulty, should the suspicion of any accident to the transit make it necessary. But it has likewise one disadvantage. Should the pillar, in settling, carry the mark a little to the east or west, the error will be greater in proportion to its nearness."

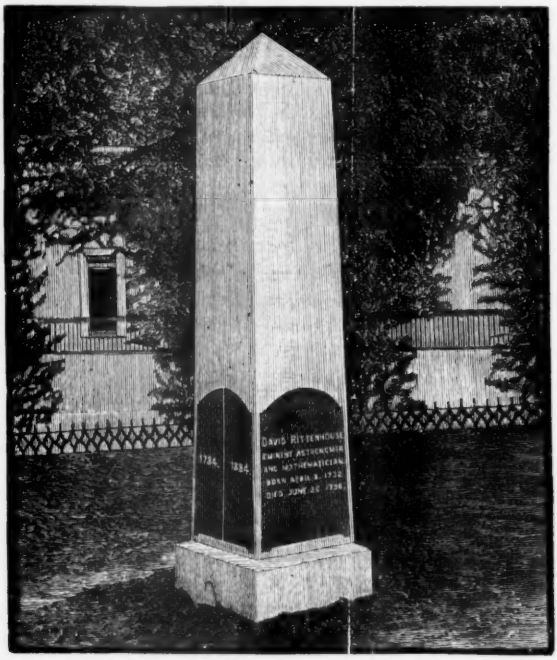
In the same letter in which he communicates about the collimator he says in a postscript that:

"For some time past I have used a single filament of silk, without knowing that the same was made use of by the European astronomers, as I have lately found it is by Mr. Herschel. But this substance, though far better than wires or hairs of any kind, is still much too coarse for some observations. A single filament of silk will totally obscure a small star, that, too, for several seconds of time, if the star be near the pole. I have lately with no small difficulty placed the thread of a spider in some of my instruments, it has a beautiful effect, it is not one-tenth of the size of the thread of the silkworm and is rounder and more evenly of a thickness. I have hitherto found no inconvenience from the use of it, and believe it will be lasting, it being more than four months since I first put it in my transit telescope, and it continues fully extended and free from knots or particles of dust.

These two improvements show his appreciation of the niceties of instrumental manipulation and considerable ingenuity. These it seems to us are the inventions for which he deserves the most enduring credit.

As to personal appearance Dr. Rittenhouse is described as somewhat tall, slender and straight, his gait quick, his movements lively. His face was of an oval form. He was of fair complexion with brown hair. His forehead was high, capacious and smooth; his eyes of a greyish color alike expressive of animation, reflection and good nature; nose, large and inclined to the aquiline; chin, broad and strong. "In short his whole countenance was indicative of intelligence, complacency and goodness, even after its characteristic marks had been in some degree impaired by sickness and years."

His fatal illness was a severe attack of cholera for which a physician was summoned June 22d and four days later, June 26, 1796, in the midst of grieving friends the leach bled him and he



Meridian Stone, recently erected at Norristown, Penn., to the memory of David Rittenhouse.

expired "without a struggle, and in the calmest manner." His last words were an expression of gratitude to a friend for some slight attention, and of confidence in the future—"You have made the way to God easier."

COLUMBIA UNIVERSITY, New York City,
May 8th, 1896.

NOTE.—Both the editor and the author wish to express their appreciation of the kindness of Mr. B. Frank Rittenhouse of Philadelphia, Secretary of the Rittenhouse Memorial Association, by whom the illustrations accompanying this article were loaned for use here.

THE STUDY OF THE VARIABLE STARS.

PAUL S. YENDELL.

II.

FOR POPULAR ASTRONOMY.

In view of certain cases which have occurred in my own practice, and of the doubts and difficulties encountered by beginners, which have come to my notice in correspondence, it seems in place here to offer a few remarks, suggestions, and cautions as to some circumstances which affect observations, and regarding their reduction.

Among those who have recently taken up the observation of the brighter variables, considerable uncertainty as to the limit of vision with the field-glasses commonly used in the work seems to exist. This is a simple question of optics, and depends on the area utilized of the objective. Without going into details, it is sufficient here to say, that the magnifying power of a good field glass is usually about four diameters; with the concave eyeglasses employed, only so much of the pencil is utilized as will enter the pupil, say two-tenths of an inch in diameter; so that with the above magnifying power, only eight-tenths of an inch of each objective goes to form the image. Now, if we assume the limit of vision of a good four-inch to be the twelfth magnitude, the limit of such a field glass will fall somewhere near $8^m.5$. Considering the low power employed, it would probably be a little higher than this. It is not enough however to be able to just see a star: those who have had long experience in this class of work consider that comparisons made near the limit of vision are very uncertain and difficult, and of scarcely any practical value. With my own telescope whose extreme limit is about $12^m.5$ I almost never carry observations below $10^m.5$, and very seldom below $10^m.0$. Sawyer's limit of work, in his revision of the Uranometria Argentina magnitudes, is set at $7^m.0$, the instrument used being a field-glass of exceptionally high quality. Mr. Sawyer is one of the best living observers of variable stars, and his experience extends over nearly twenty years. It seems to me very inexpedient to attempt observing below $7^m.5$ with the field-glass; below this brightness, an instrument of more power should be used.

COMPARISON-STARS. These have often, and in new work always, to be selected by the observer. They should, when possible, be chosen not more than four or five steps apart in brightness, as beyond three steps, comparisons are liable to considerable error.

They should when such are available, be stars which lie nearly on the same horizontal line with the variable, so that the line joining the comparison-star and the variable may be kept nearly parallel to the line joining the axes of the eyes, without having to place the head in a constrained position. In case one star is higher than the other, it will appear, if the line joining the eyes is horizontal, relatively fainter by an amount roughly proportional to the difference in altitude between the two stars. In the case of circumpolar stars, in which the relative positions change around a complete circle, this a very important matter, often introducing grave errors into the observations, and sometimes giving rise to apparently well founded suspicions of variation in stars actually constant: in this connection, the reader is referred to a paper published by me in the Astronomical Journal, Vol. XIV, p. 14, which deals with two cases of this kind. On this account, all cases of suspected variability in circumpolar stars are to be looked upon with extreme suspicion, if the apparent period be nearly commensurate with a day or a year, and only to be accepted after long and critical examination.

The only tolerably certain ways of avoiding this error are, to select comparison-stars as above suggested, and to form the unvarying habit of looking at the stars alternately in observing, glancing from the one to the other, and not looking at both at once if it can be avoided. The cause of the difficulty appears to be that the lower half of the retina, on which the image of the upper star falls, is less sensitive than the upper half, a difference due, probably, to its sensibility being blunted by constant exposure to the light of the sky, while the images of the far less luminous objects below the horizon fall upon its upper half.

In observing stars of marked and strong red color, such as Mira and R Leonis, care should be taken to make the comparisons with great deliberation, looking long at the red star, as the difference in brightness between a white and a red star is not only rendered much more difficult of estimation by the difference in color, but, from the fact that the red rays affect the retina more slowly, the red star is very apt to be underestimated; in fact, this is almost always the case at the first glance: unless some uniform practice in this respect is adopted, such observations will be very irregular and unreliable. Cases of suspected variation in very red stars should be accepted with extreme caution, as different observers will often vary a full magnitude in simultaneous estimates of such strongly colored objects, and even the same observer will sometimes make two observations of the same object

in a single evening, which will differ as widely from each other unless some such precaution as above suggested be used. Very red stars are also affected by the presence of moonlight, which causes them to look relatively brighter: and cases of variation in a period nearly commensurate with the lunar month are always looked upon with suspicion until thoroughly examined.

In reducing observations, it is most convenient, when the limits of variation are such as to be within the range of one kind of optical aid, to use the ordinary step-scale, forming the magnitude-scale by comparisons of this with the best available magnitudes of the comparison-stars.

When, however, as in the case of Mira, the star, from being a telescopic variable, rises successively to the scope of the field-glass, the opera-glass, and the naked eye, it is difficult to establish true relations between the different step-scales, and the most convenient method of reduction will be by applying the ascertained values of the different steps directly to the magnitudes of the comparison-stars.

In these reductions, a refinement can be effected in the deduced values, by applying a system of weights devised by Argelander, and suggested to the writer in its present form by Dr. Chandler. It rests on the assumption, which seems to be justified by general experience, that the relation between two lights which will usually be estimated with most care and certainty is that of equality. Comparisons in which the variable is estimated as equal to the comparison-star are therefore given a weight which indicates about double the certainty of those near the ordinary limit of comparison (4 steps): the scheme of weight suggested by Dr. Chandler is as follows; when the stars are equal, a weight of 8 is given the comparison, and for each step of interval, this weight is lessened by 1; thus *a*1*v* would be given a weight of 7; to *a*3*v*, or *v*3*a*, a weight of 5, and so on; the weight of the final value deduced being the sum of the weights of the individual comparisons.

As an example, I will give the reduction of one of my own observations of Mira, made during the late maximum:

1896, Jan. 6, δ3v, ξ^{32} 1v, v′2ξ' (all of Cetus).

$$\begin{array}{ll} \delta \text{ is } 4.04 & \text{(Potsdam Photometric DM)} \\ \xi^{32} \text{ is } 4.50 & \text{“ “ “} \\ \xi' \text{ is } 4.70 & \text{“ “ “} \end{array}$$

$$\text{The step} = \overset{\text{M}}{0.07}.$$

	M	wt	
	4.04	8	
δ3v =	+.21	−3	
	4.25	× 5	= 21.25
	4.50	8	
$\frac{32}{5}$1v =	+.07	−1	
	4.57	× 7	= 31.99
	4.70	8	
v2$\frac{32}{5}$ =	−.14	−2	
	4.56	× 6	= 27.36
sum of weights = 18			80.60

The observed magnitude is therefore $\frac{80.60}{18} = 4^{m}.48$.

The second decimal being, from the nature of the case, very uncertain, we call the value the nearest tenth, $4^{m}.5$.

A great difficulty with the amateur who has not access to good libraries is that of obtaining reliable magnitudes of his comparison-stars, on which to base his estimates.

Up to the time of Sir John Herschel's photometric determinations, all the magnitudes which had been given in the catalogues were the results of eye-estimates, scarcely better than mere guesses, and often varying between different observers by a magnitude or more, there being no generally accepted standards. Sir W. Herschel did, it is true, make an attempt at doing something in this direction, and some of his photometers were exceedingly ingenious; but his observations were comparatively few, and were confined to a small list of stars.

Until the appearance of the *Bonn Durchmusterung*, in 1869, there was, so far as I know, no such thing as an extensive and comprehensive catalogue of star magnitudes which could claim any approach to accuracy; but since that time a number of such catalogues have been published. The *Durchmusterung* gives estimates to the nearest tenth of a magnitude, down to $9^{m}.5$, but no great accuracy is claimed for them, as each estimate is the mean of three or four estimates at the most, made in the cause of the observations for position; they are a great improvement, however, on anything which preceded them, and serve well as the basis for closer determinations.

This catalogue extends from the north pole to declination $-1°$, and contains 324,000 stars, for each of which a rough mean place for the equinox of 1855, and a magnitude, are given.

The Harvard Photometry, containing magnitudes of all the stars visible at Cambridge, down to the 6th magnitude, over

4,000 in all, was published in 1884 as Vol. XIV of the Annals of the Harvard College Observatory; and the Oxford Uranometry, from the pole to $-10°$, and containing nearly 3000 stars, appeared in England in 1885.

The former was made with the aid of the meridian photometer, an adaptation of Zöllner's form, and the latter with the wedge photometer. The Harvard Catalogue was afterward extended by the employment of a more powerful photometer of the same form, down to the 9th magnitude, and appeared in Vol. XXIII of the Annals, under the name of the photometric review of the *Durchmusterung*.

The Harvard Catalogues have been the subject of severe criticism in high quarters, on the merits of which, however, it is out of place to enter here*

In 1894 appeared the First Part the Photometric *Durchmusterung* of the Potsdam Astrophysical Observatory. This contains careful photometric determinations of the magnitudes of all the Bonn *Durchmusterung* stars down to 7.0 magnitude, from the equator to declination $+20°$; these are given to hundredths of a magnitude. An idea of their accuracy may be formed from the fact, that, within the first year from its appearance, two of the stars therein noted as suspicious, were proved to be variable by Dr. Chandler and myself.

In the southern hemisphere, we have the Uranometria Argentina of Dr. Gould. This takes in all the stars as bright as the seventh magnitude, from declination $+10°$ to the south poles The magnitudes are from careful observations made by the Argelander method, and are very reliable, having been but little changed by Sawyer's careful revision. This latter catalogue, of 3400 stars, was the work of five years, from 1882 to 1889, and appeared in 1893. It includes all the stars of the Uranometria Argentina as far south as declination $-30°$. While engaged in the observations for this catalogue, Mr. Sawyer discovered no less than seven new variables.

The fourth section of the Bonn Durchmusterung, commonly known as the "Southern Durchmusterung," appeared in 1886, and contains stars to the tenth magnitude, from declination $-1°$ to $-24°$; the magnitudes are rather more accurate than in the earlier sections.

* See papers by Chandler, *Astronomische Nachrichten*, Bd. 134, s. 355 and 136, s 85; by Pickering, *Astronomische Nachrichten*, Bd. 135, s. 217; by Kempf, *Astronomische Nachrichten*, Bd. 137, s. 225; and Potsdam Photometric D. M., pp. 491 and 500.

This was carried through by Schönfeld, and, until the appearance of the Cordoba Durchmusterung in 1895, was the southern limit of our accurate knowledge of the telescopic stars, as respects magnitude.

Of these catalogues, the most reliable seem to be the Potsdam Durchmusterung, the Bonn Southern Durchmusterung, the Uranometria Argentina, and Sawyer's Catalogue.

South of $-23°$, we have the Cordoba Durchmusterung, the section of which already published in Vols. XVI and XVII of the Cordoba Results includes the stars as far south as $-42°$ to the 11th magnitude: the number of stars catalogued in it is 340,000.

Much work has been done of late years in the determination of magnitudes by measuring the photographic images of stars, and in some quarters exceeding accuracy has been claimed for these determinations. In view, however, of the character of the images, the influence of the colors of the stars on their relative sizes, the many varying conditions of atmospheric disturbance, possible lack of uniformity in films and emulsions, and different circumstances of development, the more one knows of these measures, the less he feels inclined to trust them. In one or two cases which I have had to examine, for one of which especial accuracy was distinctly claimed, the errors have appeared to be rather greater than those of my own visual observations of the same star, made by the Argelander method.

A word as to publication. If you have any results which may be of value, by all means make them public, in such scientific publications as you may have access to; not in the daily press which would be equivalent to burying them, or at any rate would greatly discredit them; the notoriety of a newspaper astronomer is very hard to live down in scientific circles.

Put your results in concise, clear and simple language, stating all the facts of interest and possible value. Any attempt at fine writing or flowery style is as much out of place in reporting scientific work as it would be in a mathematical formula.

As a general thing, the amateur had better leave the drawing of inferences from his work to those of more extended experience and knowledge of the subject.

There is one practice among amateur observers, which seems to be becoming rather common here, and which I would distinctly deprecate. It is that of sending to some paper or periodical a report of one or two detached observations of some well known variable. Usually no authorities for the magnitudes accompany

these notices, and they are of no earthly value to any one, while they waste three valuable things, to wit: time, paper and the reader's patience. This is the sort of thing much indulged in on the pages of certain foreign reports and periodicals, and especially by correspondents of the *English Mechanic*, and has succeeded in gaining for some of the more usual transgressors the distinction of having any announcement of theirs, which from time to time succeeds in getting into astronomical publications of some authority, distinctly and pointedly disregarded.

This is a case in point of the distinction which I recently heard, made by one of the world's first astronomers, in announcing the award of the gold medal of the Royal Astronomical Society to Dr. Chandler: "It is a fortunate thing for American astronomy that we have still among us a few men who prefer reputation to notoriety."

The cases above alluded to are well on their way to the latter category, but every step of gain in this direction takes just so much from their chances of attaining to the former.

In conclusion, make your observations carefully, deliberately and thoroughly: exclude every possible source of error, in the shape of memories of ephemerides, inconvenient comparison-stars, and preconceived ideas of what the star *ought to do*. Reduce carefully and accurately to see—*not* if the star is doing what you expected, but what it *is* doing. If your observations decide nothing, do not be discouraged, but keep them for future use and comparison. Reject no observations because of apparent discordance; the rejection, if made, should be at the time of observation, not afterward. If you think you have made a discovery, reserve your judgment until you have overwhelming evidence on one side or the other; do not rush into print after one or two observations, but follow the practice of Sawyer, who has often watched a star for years before announcing his suspicions, and who has *never* announced a case of variability which has failed of confirmation.

By these means you may attain to "reputation." There is no shorter way to it.

DORCHESTER, Mass., April 11, 1896.

SOME CALCULATING MACHINES.

HERMAN S. DAVIS.

FOR POPULAR ASTRONOMY.

Perhaps no work in astronomy is so tedious as that of the computer; certainly none so susceptable of making a drudge of the one on whom such duty falls. I refer to the more simple arithmetical processes involved in that class of reductions which require more figures than fancy, more grit than genius.

To shorten such labor and to render the results not only easier of attainment but likewise less liable to error, by using instead of the fallible brain some mechanical contrivance incapable of headache or of a lapse of memory, has from an early day been the effort of many inventors.

Probably the most interesting of these early endeavors was that in the tenth century by a shepherd of the mountain pastures of Auvergne, Gerbert by name. His ingenuity was early in life manifested by the invention of an organ which should be played by the force of running water; and of a clock which he had whittled from wood with his girdle-knife. Having thus attracted to himself the attention of a Benedictine monk of Aurillac he was received by him into the monastery; became himself a monk and was sent thence to the Moorish University of Cordova—then the most famous in the world, for outside the cloud that overshadowed mediæval Europe was shining brightly the Sun on Arabian achievments in science and literature.

Being a Christian and therefore prohibited from residence in a Mussulman university, Gerbert took upon himself the garb and demeanor of a devout Mohammedan. After becoming most thoroughly skilled in all the learning of the Arabian teachers he returned in 968 to Barcelona, far in advance of all his fellow-countrymen in every branch of the quadrivium.

It was this same Gerbert who afterwards became the archbishop of Rheims and chancellor of France; and still later the head of the Roman Catholic church as pope, Silvester II. But not among the least of his many achievements was the introduction into Europe of the arabic numerals. Possessed of this powerful means of computation and of so inventive a mind he was not slow to attempt some mechanical contrivance which should even more lighten the labor of calculating. He even apprenticed himself to the trade of a turner for a short time that he might with greater skill execute his ideas. Long did he toil

over his self-appointed task, but as one writer has said: "The ingenuity which had triumphed over so many difficulties before was compelled to confess itself at last baffled. He constructed many calculating machines. They had all one common fault—they would not calculate!"

In subsequent centuries a number of other men of more or less note attempted the same problem in one or another shape. None of these efforts are known to have been successful until so recently as the latter part of the sixteenth century when Napier—he of logarithmic fame—devised "computing rods" made of ivory, hence sometimes called "Napier's bones." These are for multiplication only. They are cubical and, as may be seen from the drawing, on each face is printed the common multiplication table for that digit which stands at the top of the 'bone.' When it is desired, for example, to multiply 359 by 34 those bones which have 3, 5 and 9 respectively at the top are placed in juxtaposition at the right of the 'index-bone.' Then are written down the figures given opposite 3 of the index bone, remembering to add together the two digits which are in the same oblique parallelogram. Thus opposite 3 we have 1077 and opposite 4 is 1436; the sum of which products set down with proper regard for the position of the decimal represents the desired product. The only saving in time and nerve force and accuracy secured by this invention consists in freeing the memory from the operation of 'carrying;' but this is usually over-balanced by the time consumed in making the primary arrangement of the rods. For this reason their use has been rare.

1	0/3	1/5	1/9
2	0/6	1/0	1/8
3	0/9	1/5	2/7
4	1/2	2/0	3/6
5	1/5	2/5	4/5
6	1/8	3/0	5/4
7	2/1	3/5	6/3
8	2/4	4/0	7/2
9	2/7	4/5	8/1

Another attempt was made by the famous Pascal of whom it has been said that "of all the creations of this great man, there was none on which he more persistently wearied his genius, more unprofitably wasted his hours, or it may even be said, more rapidly wore out his life, than on this."

Grillet, horologer to Louis XIV, produced a machine which became famed far and wide, though the method of its working was kept carefully secret. Even Leibnitz, zealous for every good

work, but jealous of every work that in any degree surpassed any product of his own fertile genius, in the very height of his scientific renown, neglected the dignities and honors being showered on him by the scientific world and the monarchs of Europe and for nearly four years lived only with the single aim of rivaling Grillet in his wonderful invention.

He finally produced the best he could accomplish. It was certainly no better than that of Grillet, if, indeed it was not the same machine or a copy, as was rather loudly rumored at the time. It is significant that Grillet's apparatus had suddenly disappeared and was never heard of afterwards. It is not improbable that the scandal openly attached to Leibnitz's action was in this case somewhat better grounded than the one regarding his invention of the infinitesimal calculus.

A long list of inventors or would-be inventors follow in rapid succession but with indifferent success. So that it was not until 1822 that the problem of a calculating machine was really satisfactorily solved. This was by M. Thomas of Colmar, who called his machine an "arithmometer." One of these has been in the Observatory of Columbia University for a number of years and has worn out in service. It is a perfectly practical labor-saving device; almost its only fault is that its wheels are subject to rapid wear, the material used being brass.

At the World's Fair in Chicago a German manufacturer had on exhibition a modification of the Thomas arithmometer. It is known as the Brunsviga. At the close of the Fair this was purchased by President Seth Low who presented it to the Observatory of his University, where it has been in constant use ever since. It has proved itself of such great utility and convenience that two others were ordered and are now likewise in use.

It is not the purpose of this article to treat of quite a different class of machine of which Babbage's difference engine is a type; and mere adding machines are so numerous nowadays in this country as to scarcely need mentioning. But because of the simplicity of the Brunsviga and the universality of its operations and because in its construction and manipulation it is practically the same as the Thomas, we think it merits a short description for the benefit of those who may not have the opportunity of inspecting one and profiting by its utility.

The power of this machine to perform any conceivable arithmetical operation seems most marvelous. The writer has often noticed, with amusement, on the faces of persons even of wide experience and culture, when watching for the first time how rapidly

an extended problem may be solved, a look of astonishment and bewilderment that would make it seem they were for an instant endeavoring to convince themselves of the reality of the supernatural, or that its operator was in league with the Prince of the Magic Art. Yet perhaps to nothing is the fable of Columbus' egg more applicable.

Reference to the illustration will make evident that there are three distinct faces for figures. The upper curved face, where there are nine slits in each of which slides a metal finger, we will designate by A; the lower face on the left by B; and the lower one on the right by C. The faces B and C show but a row of figures, each of which is on a separate wheel. Each wheel in B has on it in consecutive order the digits 0 to 9 and in reverse order 8 to 1. In C each wheel has the ten digits only.

Beneath the face A is a cylinder into which are set cubical steel needles similar (except in size) to the fine steel points on the barrel of a music-box, only that in the present case they are moveable in or out from the surface of the cylinder at the will of the operator. They are controlled by eccentric wheels attached separately to each of the fingers projecting through the slits where they may be reached by the operator. If all the fingers be set at zero none of these needles will project above the surface of the cylinder, but if the fingers be set at 7-2-5-2-4 as shown in the illustration, then by opening the machine one would find on the cylinder below the figure 7 seven needles protruding about one-quarter of an inch; two below the figure 2, and so on. Now if the handle be turned through one complete revolution, each of these various needles will operate on the cogs of the wheels in the C face—the 7 needles turning the wheel so as to show the figure 7 in the C face, etc. Thus far the work is exceedingly simple.

But turn the crank once more and what would be the result? Obviously the same operation would be performed, each wheel however, starting in its motion from the last indication. Were there no more mechanism than that already described each wheel, would be acted on independently of its neighbor and the result would be 4-4-0-4-8. This is wrong; for evidently we should have the sum of 72524 and 72524. What is needed, therefore, is a contrivance which shall perform automatically the process known as 'carrying.' This is accomplished very ingeniously. In addition to the nine needles in the circumference of the cylinder A there are extra needles which constantly protrude from the surface but are ordinarily bent to one side by springs so as to be outside the range of the cogs of the C wheels. When, however, the latter

reaches 9, a pin there causes a finger to spring out which in turn, as the handle revolves, forces the bent needle into the cog of the next higher wheel in the decimal scale at C causing it to advance one digit and no more. The springs then, of course force all parts back to their original inactivity until there shall again be need of 'carrying.'

In this way the same number may be added to itself as many times as one may turn the crank. As successive additions of the same quantity are but multiplications of that quantity by the number which expresses the frequency of revolution of the crank, it is seen that the machine is available for both addition and multiplication. One would hardly desire to turn the handle 12578 times, say, if that be the multiplier; so just as ordinarily the the crank is turned 8 times, then the whole BC section is made to slide along one decimal place, whereupon the crank may be turned 7 times more instead of 70 times at unit's place.

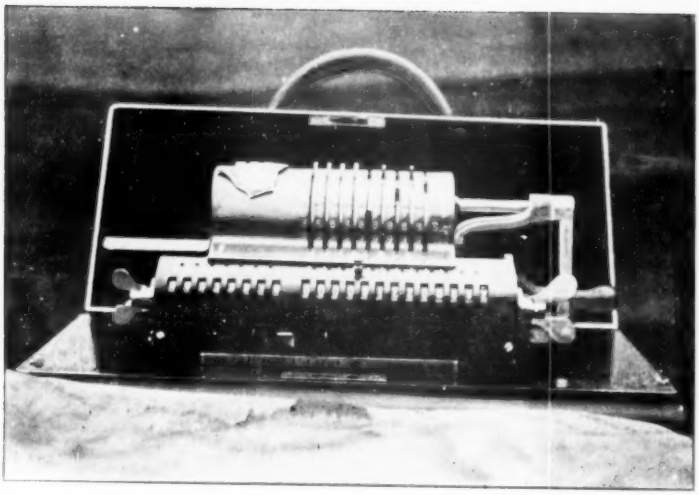
Subtraction being the reverse process of addition, the same operations are performed as in addition except that the crank is turned backwards; thus undoing the work it may have been supposed to have previously done. The cylinder A is, for this purpose constructed symmetrically with respect to the 'carrying' needles. Division is only successive subtraction of a definite divisor, just as multiplication is continued addition.

If available only for separate, isolated problems such as these this instrument would be almost invaluable, but after all merely a toy compared with its real capabilities.

Determining at once the sum of a vast number of separate products of numbers consisting of many digits intertwined with algebraic signs worse than is an African jungle with rattan, as for instance in forming normal equations in least square work where the individual products are not needed, is but one modest test of the manifold combinations which are being daily performed with it. In fact, for least square solutions the machine is in its glory. In making the eliminations by the Gaussian method it is pre-eminently superior to any other device whatever—logarithmic or other.

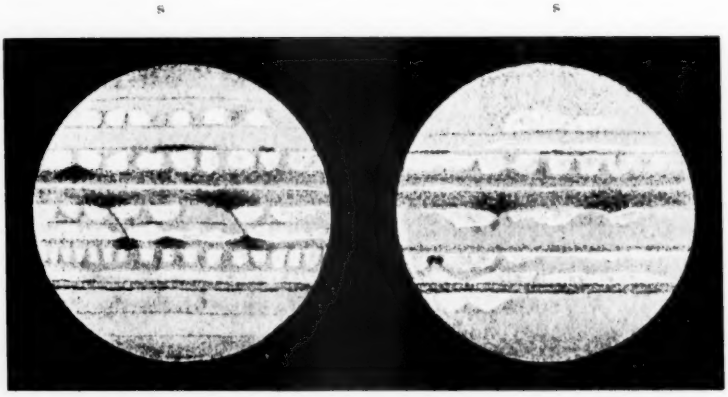
Most facile skill in its use comes of course only by practice, the elements of its use can be learned in five minutes. On it work can be done from six to twelve times faster than by other processes; and constant use keeps revealing scores of 'short turns' not hinted at in the manufacturer's handbook; and which can be appreciated only by those who may make a practical application of them.

PLATE II*a*.

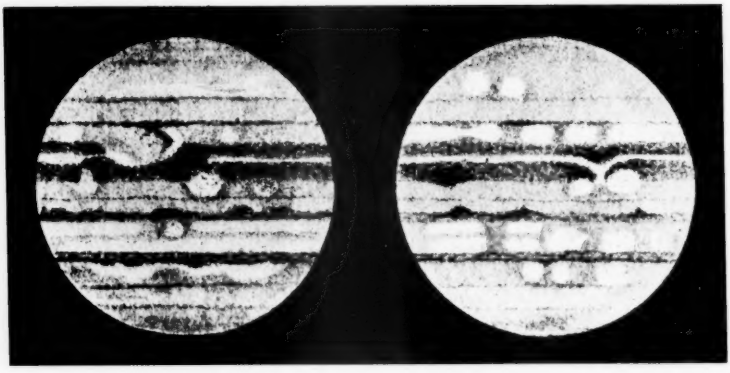


THE BRUNSVIGA.

PLATE III.



No. 1. λ 129° 19′ No. 2. 273° 36′



No. 3. λ 15° 6′ No. 4. 324° 26′

No doubt in the near future decided improvements will be made in the Brunsviga but it has now been made clear in what way this may be done most satisfactorily and most economically. When we look back at the numerous attempts that were made from Gerbert's day to the present to produce an instrument which should have the power and the usefulness that the little machine here pictured really does have; and when we remember that it has taken a thousand years to accomplish this satisfactory result, we cannot but learn the lesson that little things lead to greater; that each individual may add his mite to help form the grand total of all; and that whether he personally enjoy its benefits or not, the world at large has profited by his labors—if he shall have worked with enthusiasm, with zeal and with a definite purpose in view.

COLUMBIA UNIVERSITY, New York City,
April 30 1896.

THE PHYSICAL ASPECT OF JUPITER IN MARCH, 1896.

HENRY F. GRIFFITHS.*

The Planet this year is in an extraordinary state of disturbance. There are generally large numbers of markings, both dark and white, visible. The latter spots are seemingly very much plainer and easier objects than of late oppositions. My instrument is a Calver reflector of 6 inches clear aperture, on alt-azimuth stand.

DESCRIPTION OF DRAWINGS.

No. 1. March 22nd. $\lambda = 129° 19'$. Power 140. Air = 1. $9^h\ 0^m$ G. M. T. This night for definition is by far the best I have seen this year; every marking was seen and held with a wonderful distinctness. The polar regions are of different colours, that of the South being a greenish mauve and the North blue. The belts are generally of a dark chocolate, more especially the South Equatorial. At this observation the S. S. S. & S. S. Temperate belts were easily seen. In the S. S. Zone were six white spots. There were none in the S. Temperate Zone. On the S. Temperate belt were two dark markings. The South Tropical Zone is much disturbed having seven distinct white spots visible. We now come to the South Equatorial belt. This is divided by a narrow line of light. Both borders are very uneven. There is a curious pointed shading at the preceding end on the South border and two on its North edge, with which are connected two wisps which cross the Equa-

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torial Zone and join the North Equatorial belt. The equatorial belt is easily visible. On the Equatorial Zone are 12 white spots. The North Equatorial belt is very uneven on its Southern edge, and shows three pointed shadings. On the South portion of the North Tropical Zone I counted 16 white spots. This Zone is divided in the centre by a very faint line which requires the best air to make out well. One of the most curious markings is the duplicity of the North Temperate band. Its northern border is the darker of the two and to which there are apparently several spots in direct contact. The North Temperate Zone has 5 oval white spots. The N. N. & N. N. N. Temperate bands were visible.

No. 2. March 23rd. $\lambda = 273°\ 36'$. Power 140. Air 3. $8^h\ 50^m$ G. M. T. There are several curious markings visible here, though the air was not good. The two shaded regions on the Northern border of the South Equatorial belt and the double dark spot on the North Tropical Zone. I saw 4 white spots on the South Tropical Zone and 5 white markings on the North Tropical.

No. 3. March 24. $\lambda = 15°\ 6'$. Power 140. Air 2. $7^h\ 30^m$ G. M. T. Here is the very interesting region of the Great Red Spot. This most marked spot is still visible, particularly the following border. The S. Equatorial belt again shows the shoulder preceding the spot. On the South Equatorial belt there are two dark round spots with a white one between them. There is also a white oval cloud just above the north edge of the belt and closely following the Great Red Spot. The south edge of the Equatorial belt is again very uneven, particularly at its following portion. The North Temperate band exhibits several dark spots on its northern edge.

No. 4. March 28. $\lambda = 324°\ 26'$. Power 140. Air 3 $8^h\ 50^m$ G. M. T. The most remarkable feature is the rift in the South Equatorial belt, by which the white division seems to flow into the Equatorial Zone. There are two white spots preceding and following. The North Equatorial belt again shows the pointed shadings on its south edge. The North Tropical Zone is again divided, at its preceding half. There are two large cone shaped markings also on this region.

The planet this apparition has an indescribable beauty, notwithstanding the disturbed state of the weather, and the various interesting markings I have seen plainer than ever before. I consider a reflector far before any refractor for portraying planetary detail.

SHERWOOD VILLA, Angles Road Streatham, Near London, England.

MR. HOUGH'S RESEARCHES ON THE PERIODIC LAW OF LATITUDE-VARIATION.*

The discovery of the periodic law of latitude-variation, due mainly to the researches of Dr. S. C. Chandler, has given rise to several attempts to reconcile theory with observation, by including in the dynamical theory of the Earth's rotation possible effects of the change of form or of the mobility of the parts of the Earth. In the 'Astronomical Journal,' No. 345 (see 'Observatory,' August 1895), Professor R. S. Woodward has employed the equations of motion of a body of changing form to show that the flow of the Earth's material relatively to its principal axes may give rise to a considerable modification in the duration of the Eulerian cycle, but the equations used are powerless to give any indication of the extent of this modification, or, in fact, even of its sign.

In recent papers Mr. S. S. Hough, Isaac Newton Student in the University of Cambridge, has endeavored to evaluate the disturbing angular velocities and the consequent modifications in the period on two different hypotheses as to the constitution of the Earth. In the former the interior of the Earth is assumed to be in part fluid, while the outer crust is treated as rigid. The results, however, are of a negative character, showing that such a constitution would lead to a phenomenon in direct contrast to that which is observed, namely a shortening instead of a lengthening of the period. In the second paper, the Earth is regarded as solid throughout, but the material of which it is composed is supposed capable of elastic distortion. The difficulties of the mathematical treatment necessitate the neglect of possible variations in the density and elastic quality of the Earth's material, and the case considered is, therefore, that of a homogenous spheroid composed of isotropic, incompressible material. Such a spheroid, if of the same size and mean density as the Earth, the external figure being such that it is free from strain in its interior when rotating uniformly in a sidereal day, would oscillate, if rigid, in a period of 232 days. If, however, the spheroid be composed of elastic material of the same degree of flexibility as steel, it is estimated that the period would be prolonged to 335 days; but assuming that the effect of heterogeneity is to further prolong the period in the ratio 305:232, the period for the actual Earth supposed of the

* "On the Oscillations of a Rotating Ellipsoidal Shell containing Fluid," Phil. Trans. 1895 A, and "On the Rotation of an Elastic Spheroid," Proc. Roy. Soc., March 1896.

rigidity of steel is estimated as 440 days. It is therefore concluded that the observed extension from 305 days to 427 days may be adequately accounted for by supposing that the resistance to distortion of the solid parts of the Earth is rather greater than that of steel.

The latter problem has been previously treated by Professor Newcomb ('Monthly Notices,' March 1892), who gives a simple geometrical explanation of the phenomenon. Mr. Hough enters into a full analytical discussion of it, which confirms in the main the procedure of Professor Newcomb, but discloses a slight error in its details.

Another cause which may tend to modify the Eulerian period is to be found in the mobility of the ocean and of the atmosphere. The inclusion of the effects due to this latter cause will of course lead to a modified estimate of the Earth's rigidity. According to Newcomb the period of latitude-variations will be longer with the ocean in its actual condition than it would be if the ocean were rigidly attached to the solid Earth, and consequently the extension of the Eulerian period is to be explained only in part by elasticity. We should therefore obtain an increased estimate of the Earth's rigidity. In Mr. Hough's opinion, however, Newcomb's conclusions as to the effects of the ocean are not well-established, and further research is necessary to determine the nature of the modification due to this cause. He, however, accepts the view that the chief factor which accounts for the prolongation of the period is elasticity, and that the estimate of the Earth's rigidity deduced from Chandler's period without taking account of the ocean, will not be modified to any considerable extent when the effect of the latter is included.—*The Observatory*.

THE APPROACHING TOTAL ECLIPSE OF THE SUN*

The duration of a total eclipse is so very brief that the utmost use must be made of every moment. Good organization is accordingly the key-note of success, and to this end a considerable amount of preliminary inquiry and discussion is essential. The arrangements for the Government expeditions have been made by a joint committee of the Royal and Royal Astronomical Societies, which has met at intervals during the last three years. The principal objects to be undertaken are to secure permanent and unbi-

* Extracts from an article, as titled above, by A. Fowler in *Knowledge*, June, 1896.

ased photographic records of the corona, and of the spectra of the various parts of the solar surroundings. Such records are considered the first duty of an organized eclipse expedition, but if instruments and observers be available the programme may be extended to include special pieces of research.

At the Japanese station the Astronomer Royal will employ the Thompson photoheliograph of the Royal Observatory, giving an image of the Sun nearly four inches in diameter. It is not expected that the filmy outlying parts of the corona will be bright enough to impress their images on this large scale; but the very beautiful pictures obtained by Schæberle in 1893 encourage us to hope that the finer structure of the inner corona will be depicted with almost telescopic minuteness.

Professor Turner will use well-tried instruments, which, although yielding pictures on a small scale, will give results strictly comparable in every particular with those of former eclipses. The images will be small and bright, and a special endeavor will be made to register the very delicate regions of the outer corona. One set of pictures will be on a scale of a half-inch to the Sun's diameter, and another one and one-half inches, the latter being enlarged by a "telephoto" lens.

At the Norwegian station the arrangements for photographing the corona will be in the capable hands of Dr. Common. Part of his outfit will probable consist of a modified Cassegrain reflector, giving large images of the corona; and other instruments which he will employ will give relatively small but bright images similar to those which Professor Turner hopes to secure in Japan.

During the coming eclipse there will be a new departure in the instrumental arrangements for photographing the corona. In place of the equatorials which have almost invariably been employed up to the present time, the photographic telescopes will be fixed, and will receive the light of the corona after reflection from the mirror of a "cœlostat." The new instrument is an exceedingly portable form of heliostat which has recently been brought to the front by M. Lippmann. It consists simply of a mirror which is made to revolve on a polar axis in its own plane at the rate of one revolution in forty-eight hours, in the same direction as the apparent diurnal motion of the heavens. In a mirror so mounted the image of any celestial object whatever appears stationary, and a telescope pointed at the mirror in any direction will have a constant field of view.

The official observers, however, will not have the photographic field to themselves, although they will naturally have a monop-

oly of work which can only be done by large instruments. Many members of the British Astronomical party will make use of their cameras and telescopes, and Mr. Lunt will employ the three-inch photographic telescope with which he has been so conspicuously successful in stellar photography. The American observers in Japan will be chiefly occupied in photographing the corona on a large scale with objectives of long focus, and the same method will be adopted by the Russian observers at Olekminsk. Several ordinary cameras will be at work at the mouth of the Obi, and at Enontekis clock-driven cameras will be employed.

If the photographs of the corona are as successful as every one desires, they should throw light on various points of solar physics. The larger pictures should especially enable us to learn something of the solar currents, "lines of force," or whatever it may be that determines the peculiar structure of the solar appendages. The distribution of coronal matter in different solar latitudes should also be revealed, and an investigation of its connection with the sunspot zones will become possible. Another point on which the photographs permit inquiry is the law of decrease in the intensity of the corona in passing outwards. Finally, if success is met with all along the line, it will be possible to determine if the corona changes its form in the interval of about one and a half hours intervening between the observations in Norway and Japan. It may be remarked, however, that previous experience does not favor the idea of such rapid changes.

* * * * * *

Captain Hills has provided himself with a very fine slit spectroscope, having four quartz prisms and a condensing lens of four and three-quarter inches aperture, with which he hopes to photograph the spectrum of the corona. The instrument will be fixed on a horizontal base, and the rays of light from the eclipsed Sun will be reflected into it by a heliostat of the ordinary form.

In Norway the principal spectroscope to be employed by Professor Lockyer and the writer is a prismatic camera of six inches aperture, which was very successfully used in Africa in 1893. The instrument is mounted as an equatorial, and the arrangements provide for the exposure of a large number of plates in quick succession. An integrating spectroscope will also be employed by Professor Lockyer.

We understand that Dr. Copeland will be armed with a prismatic camera, while Mr. Evershed will employ spectroscopes of both forms. The Russian party at Olekminsk will also be provided with a slit spectroscope arranged to photograph the coronal

spectrum, and this method will probably be followed by M. Deslandres in Japan.

As the photographic plates cannot yet be relied upon to completely delineate the less refrangible parts of the spectrum under the special circumstances of an eclipse, they will be supplemented by visual observations. Mr. Maunder intends to use a slitless spectroscope to study specially the distribution and extension of the green ring corresponding to 1474 K, and it is hoped that other observers will similarly record the appearances of the yellow line of helium and the red line of hydrogen.

Apart from adding to our scanty knowledge of the undoubted coronal spectrum, and its possible variation from one eclipse to another, one of the chief points on which it is hoped that the spectroscopic work will enlighten us is the location in the Sun's atmosphere of the vapors which produce the Fraunhofer lines. There is little doubt that the base of the chromosphere—the so-called "reversing layer"—is rich in bright lines, but the precise relation of these to the dark ones of the Fraunhofer spectrum is by no means understood.

Among the more special investigations which will probably be undertaken one may mention that Dr. Downing will make polariscopic observations, with the view of ascertaining the proportion of reflected to intrinsic light in the corona

Photometric observations, having for their object the determination of the general brightness of the corona, will probably also be made at some of the observing stations, easy methods for doing this having been suggested by Mr. Maunder and Mr. Lunt. Mr. Crommelin has drawn attention to the desirability of recording the attendant phenomena, such as the mysterious "shadow bands," and some of the observers who have no telescopes will doubtless keep a lookout for such appearances.

The Russian observers at Enontekis will study the relation of the coronal spectrum to that of helium, and there is little doubt that M. Deslandres will endeavour to test the truth of his conclusion from the observations of 1893, that the corona shares in the general solar rotation. Professor Vosnesensky's object during the eclipse will be to investigate the meteorological effects which accompany the temporary obscuration of the Sun's light and heat.

From what has been said it is evident that there will be no lack of observers during the forthcoming eclipse, and all friends of science will wish them the utmost success in the various researches undertaken.

PRACTICAL SUGGESTIONS.

THE PLANETARY EPHEMERIS.

J. MORRISON, M. A., M. B., PH. D.

FOR POPULAR ASTRONOMY.

Two systems of polar coördinates are employed in the planetary ephemeris:

1st. The heliocentric consisting of the heliocentric longitude, and latitude and the radius vector, having the centre of the Sun as origin and the plane of the ecliptic and the *mean* equinox of date as the fundamental plane and point of reference. If the true longitude, or the longitude from the true equinox, is required, it will be necessary to apply the nutation in longitude as given on page 278 of the *American Ephemeris*.

2d. The geocentric consisting of the apparent R. A. and Decl. and the distance, having the centre of the Earth as origin and the equinoctial and *true* equinox as the plane and point of reference. In this system the apparent R. A. and Decl. are given, that is to say, the true R. A. and Decl. have been corrected for aberration.

The heliocentric coördinates are deduced directly from the planetary tables and are computed for every 2d day for Mercury, for every 4th day for Venus, Mars, Jupiter and Saturn, and for every 8th day only for Uranus and Neptune.

The daily motion in longitude and latitude is computed by equation (15). The next column gives the correction to be applied to the heliocentric longitude to reduce it to the orbit longitude, the latter being equal to the longitude of the node plus the angular distance of the planet from the node and is computed as follows:

Let AV* represent the ecliptic, PV′ the orbit of a planet, V the vernal equinox and ☊ the ascending node; take ☊V′ = ☊V, and draw PA perpendicular to AV, then VA is the heliocentric longitude, AP the heliocentric latitude and PV′ the orbit longitude of the planet; and ☊V is the longitude of the node which we will denote by ☊. Let PA = β, AV = λ, P☊ = l and A☊P = i, the inclination, then it is evident that the correction to the longitude AV in order to reduce it to the orbit longitude PV′, is the difference between P☊ and A☊, which is a function of A☊ and i. The inclination and longitude of the node are found in the elements of the orbit as given in the planetary tables, but they can be com-

* A cut showing this will appear in the August number. Copy lost in transit.

puted from the heliocentric longitude and latitude as given in the Ephemeris; thus, let λ and λ' and β and β' denote any two longitudes and latitudes, then from the right sperical triangle APΩ we have, AΩ being equal to $\lambda - \Omega$,

$$\sin(\lambda - \Omega) = \tan\beta \cot i$$

and also

$$\sin(\lambda' - \Omega) = \tan\beta' \cot i \qquad (37)$$

hence we have

$$\frac{\sin(\lambda - \Omega)}{\sin(\lambda' - \Omega)} = \frac{\tan\beta}{\tan\beta'}$$

or

$$\frac{\sin(\lambda - \Omega) + \sin(\lambda' - \Omega)}{\sin(\lambda - \Omega) - \sin(\lambda' - \Omega)} = \frac{\tan\beta + \tan\beta'}{\tan\beta' - \tan\beta'}$$

or

$$\frac{\cos\frac{1}{2}(\lambda + \lambda' - 2\Omega)\cos\frac{1}{2}(\lambda - \lambda')}{\sin\frac{1}{2}(\lambda + \lambda' - 2\Omega)\sin\frac{1}{2}(\lambda - \lambda')} = \frac{\sin(\beta + \beta')}{\sin(\beta - \beta')}$$

whence

$$\tan\left(\frac{\lambda + \lambda'}{2} - \Omega\right) = \frac{\sin(\beta + \beta')}{\sin(\beta - \beta')}\tan\frac{1}{2}(\lambda - \lambda') \qquad (38)$$

which determines

$$\frac{\lambda + \lambda'}{2} - \Omega$$

and thence Ω, and from (37) we have

$$\tan i = \frac{\tan\beta}{\sin(\lambda - \Omega)} = \frac{\tan\beta'}{\sin(\lambda' - \Omega)} \qquad (39)$$

We also have from the triangle APΩ

$$\tan(\lambda - \Omega) = \cos i \tan l$$

or

$$\tan l = \tan(\lambda - \Omega)\sec i \qquad (40)$$

from which l may be found and then $l - (\lambda - \Omega)$ which is the correction required, but a more convenient formula may be deduced from (40) by expanding it into a series by means of the exponential values of $\tan(\lambda - \Omega)$ and $\tan l$; thus we easily find

$$l - (\lambda - \Omega) = \tan^2\frac{1}{2} i \sin 2(\lambda - \Omega) + \frac{1}{2}\tan^4\frac{1}{2} i \sin 4(\lambda - \Omega) + \text{etc.}$$

or in seconds of arc

$$l - (\lambda - \Omega)'' = \frac{\tan^2\frac{1}{2} i \sin 2(\lambda - \Omega)}{\sin 1''} + \frac{\tan^4\frac{1}{2} i \sin 4(\lambda - \Omega)}{\sin 2''} + \text{etc.} \qquad (41)$$

In using these formulæ we must estimate λ and λ' from the same equinox, that is we must allow for the precessions during the interval and if extreme accuracy be required, we must take

into consideration the motion of the node. No node is stationary; those of the planets all regress on the ecliptic. The motion of Venus's node for instance is about 17″.7 per year and when we take into account the annual precession of 50″.2, the longitude of the node will increase 32″.5 annually, and similarly for all the other planets.

EXAMPLE: Let it be required to find the reduction of longitude to the orbit in the case of Venus for 1895, July 7, G. M. noon.

From the Ephemeris (page 255) we have

July 3,	λ'	=	232	48	20.1	β' =	+ 1	19	26.0
" 7,	λ	=	239	10	55.3	β =	+ 0	58	6.2
hence $\frac{1}{2}(\lambda - \lambda')$ =			3	11	17.6	$\beta + \beta'$ =	+ 2	17	32.2
$\frac{1}{2}(\lambda + \lambda')$ =			235	59	37 7	$\beta - \beta'$ =	− 0	21	19.8

$\sin(\beta + \beta') = 8.6020287$
$\sin(\beta - \beta') = 7\ 7927142n$
$0.8093145n$
$\tan \frac{1}{2}(\lambda - \lambda') = 8.7458745$
$\tan\left(\frac{\lambda + \lambda'}{2} - \Omega\right) = 9.5551890n$
$\frac{1}{2}(\lambda + \lambda') - \Omega = 160° 14' 52''.42$
$\frac{1}{2}(\lambda + \lambda') = 235\ 59\ 37\ .70$
$= \Omega\ 75\ 44\ 45\ .28$

$\tan \beta = 8.2279685$
$\sin(\lambda - \delta) = 9.4549731$
$\tan i = 8.7729954$
$i = 3° 23' 35''.53$
$\tan^2 \frac{1}{2} i = 6.9431683$
$\sin 2(\lambda - \Omega) = 9.7375965n$
$6.6807648n$
$\sin 1'' = 4.6855749$
$-98''.898 = 1.9951899n$
$\sin 4(\lambda - \delta) = 9.9616n$
$3.9479n$
$\sin 2'' = 4.9366$
$-.091 = 8.9613n$

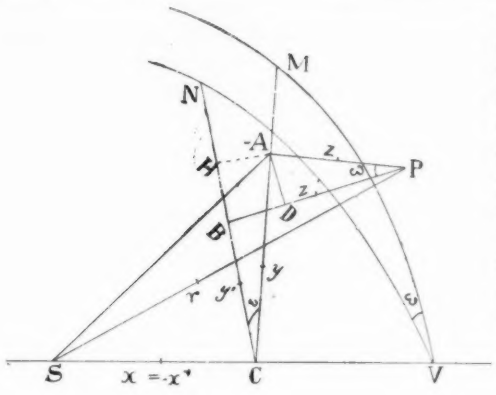
therefore $l - (\lambda - \Omega) = -98\ .989 = -1'\ 38''.989$ or $-1'\ 39''.0$.

which agrees with the Ephemeris.

The planetary tables always contain a table which gives the reduction to longitude or to orbit and from which it can be taken by simple inspection.

GEOCENTRIC CO-ORDINATES.

The heliocentric coördinates are transformed into geocentric by the following process: Let S represent the Sun, P the planet and SV the direction of the vernal equinox, and conceive a plane NMPC to pass through the planet and perpendicular to SV, and



let this plane intersect the planes of the ecliptic and equator in the lines CM and CN respectively. Draw PA perpendicular to CM and join SP, then the angles SAP, SCM and SCN are right angles, ASV is the heliocentric longitude $= \lambda$, and ASP the heliocentric latitude, $= \beta$, of the planet and SP the radius vector $= r$, and MCN $= \omega$, the obliquity of the ecliptic. Let x, y, z, be the rectangular coördinates of P, that is $x =$ SC, $y =$ CA and $z =$ AP, then we shall evidently have

$$\begin{aligned} x &= r \cos \beta \cos \lambda \\ y &= r \cos \beta \sin \lambda \\ z &= r \sin \beta \end{aligned}$$

Draw PB perpendicular to CN, AD perpendicular to PB and AH parallel to PB and let x', y' and z' be the rectangular coördinates of P referred to the plane of the equator, then since the angle MCN $=$ APB $= \omega$ the obliquity, we have.

$$\begin{aligned} x' &= \text{SC} = x \\ y' &= \text{CB} = \text{HC} - \text{AD} \\ &= y \cos \omega - z \sin \omega \\ z' &= \text{PB} = \text{AH} + \text{PD} \\ &= y \sin \omega + z \cos \omega \end{aligned}$$

substituting the values of x, y and z, we get

$$\begin{aligned} x' &= r \cos \beta \cos \lambda \\ y' &= r \cos \beta \sin \lambda \cos \omega - r \sin \beta \sin \omega \\ z' &= r \cos \beta \sin \lambda \sin \omega + r \sin \beta \cos \omega \end{aligned}$$

and putting $\quad k \cos \theta = r \cos \beta \sin \lambda$

and $\quad k \sin \theta = r \sin \beta$

that is $\quad \tan \theta = \dfrac{\tan \beta}{\sin \lambda}$ and $k = \dfrac{r \sin \beta}{\sin \theta}$

we shall have

$$\begin{aligned} x' &= r \cos \beta \cos \lambda \\ y' &= k \cos (\theta + \omega) \\ z' &= k \sin (\theta + \omega) \end{aligned} \qquad (42)$$

which are the equatorial rectangular coördinates of the planet referred to the centre of the Sun as origin, the plane of the equator and true equinox as the plane and point of reference. We must now transfer the origin to the centre of the Earth; and if X, Y and Z denote the Sun's equatorial coördinates, we must have for the geocentric equatorial coördinates of the planet

$$X + x',\ Y + y' \text{ and } Z + z'$$

and therefore, if α, δ and Δ be the true R. A., Decl. and distance of the planet we have

$$\begin{aligned} X + x' &= \Delta \cos \delta \cos \alpha \\ Y + y' &= \Delta \cos \delta \sin \alpha \\ Z + z' &= \Delta \sin \delta \end{aligned}$$

whence

$$\begin{aligned} \tan \alpha &= \frac{Y + y'}{X + x'} \\ \tan \delta &= \frac{Z + z'}{Y + y'} \sin \alpha = \frac{Z + z'}{X + x'} \cos \alpha \qquad (43) \\ \Delta &= \frac{Z + z'}{\sin \delta} \end{aligned}$$

By these formulæ the R. A., Decl. and distance are computed for every second, fourth, etc., days as the case may be and then interpolated for all intermediate days; the quantities are then differenced and the daily or hourly motion in R. A. and Decl. computed by (15).

We can now compute the aberration in R. A. and Decl. by (10) using the constant of aberration as given in the American Ephemeris, viz: 20″.4451 which corresponds to an interval of 497.82 seconds for the passage of light from the Sun to the Earth.

If then m and n denote the *hourly* motion in R A. and Decl. respectively we shall have

$$\begin{aligned} \text{Aberration in R. A.} &= \frac{497.82}{3600} \Delta m = [9.140776]\, \Delta m \\ \text{Aberration in Decl.} &= \frac{497.82}{3600} \Delta n = [9.140776]\, \Delta n \qquad (44) \end{aligned}$$

the quantity in brackets being the logarithm of the coefficient of Δm or Δn.

When the aberration is applied with its proper sign to the R. A. and Decl. as given by (43), we obtain the apparent R. A. and Decl. as tabulated in the Ephemeris. It will not generally be necessary to re-difference the quantities for the purpose of recom-

puting the hourly variation in R A. and Decl. In the American Ephemeris, one of the geocentric coördinates—the distance—is tabulated with the heliocentric coördinates, but in the English Nautical Almanac, the two systems of coördinates are tabulated side by side on the same page, a far more convenient arrangement, the columns containing the hourly variation in R. A. and Decl. being omitted.

We will now apply the preceding formulæ to the calculation of the apparent R. A., Decl. and distance of Venus in Sept. 17, 1895.

The heliocentric coördinates are,

$\lambda = 353^\circ\ 14'\ 43''.6$, $\beta = -\ 3^\circ\ 21'\ 52''.0$, $\log r = 9.8614852$ and

$$\omega = 23^\circ\ 27'\ 19''.3$$

Applying the nutation in longitude $+\ 5''.45$ (page 278) we have for the *true* longitude, $\lambda = 353^\circ\ 14'\ 49''.05$

$$\begin{array}{rl} \tan\beta = & 8.7692903n \\ \sin\lambda = & 9.0703708n \\ \hline \tan\theta = & 9.6989195 \\ \theta = & 206\ 23\ 44.6 \\ \omega = & 23\ 27\ 19.3 \\ \hline \omega + \theta = & 230\ \ 1\ \ 3.9 \end{array} \qquad \begin{array}{rl} \log r = & 9.8614852 \\ \sin\beta = & 8.7685411n \\ \hline & 8.6300263n \\ \sin\theta = & 9.6504747n \\ \hline \log k = & 8.9795516 \end{array}$$

$$\begin{array}{rl} \log r = & 9.8614852 \\ \cos\beta = & 9.9992508 \\ \cos\lambda = & 9.9969765 \\ \hline \log x' = & 9.8577125 \\ x' = & 0.7206303 \\ X = & -0.9997166 \\ \hline x' + x = & -0.2790863 \end{array} \qquad \begin{array}{rl} \log k = & 8.9795516 \\ \cos(w+\theta) = & 9.8079071n \\ \hline \log y' = & 8.7874587n \\ y' = & -0.0612997 \\ Y = & +0.0910230 \\ \hline y + Y = & +0.0297233 \end{array} \qquad \begin{array}{rl} \log k = & 8.9795516 \\ \sin(w+\theta) = & 9.8843667n \\ \hline \log z' = & 8.8639183n \\ z' = & -0.0731002 \\ Z = & +0.0394947 \\ \hline z' + Z = & -0.0336055 \end{array}$$

$$\begin{array}{rl} \log(y' + Y) = & 8.4730970 \\ \log(x' + X) = & 9.4457384n \\ \hline \tan\alpha = & 0.0273586n \\ \alpha = & 173^\circ\ 35'\ 14''.84 \\ = & 11^h\ 55^m\ 40^s.99 \end{array} \qquad \begin{array}{rl} \log(z' + Z) = & 8.5264104n \\ \log(y' + Y) = & 8.4730970 \\ \hline & 0.0533134n \\ \sin\alpha = & 9.0249094 \\ \hline \tan\delta = & 9.0782228n \\ \delta = & -\ 6^\circ\ 49'\ 40''.19 \end{array} \qquad \begin{array}{rl} & 8.5264104n \\ \sin\delta = & 9.0751317n \\ \hline \log\Delta = & 9.4512787 \end{array}$$

On page 228 we find $m = -\ 5^s.503$ and $n = +\ 37''.46$.

$$\begin{array}{rl} \text{Const. log} = & 9.140776 \\ \log\Delta = & 9.451279 \\ \log m = & 0.740599n \\ \hline \text{Aber. in R. A.} - 0^s.215 = & 9.332654n \end{array} \qquad \begin{array}{rl} & 9.140776 \\ & 7.451279 \\ \log n = & 1.573568 \\ \hline \text{Aber. in Decl.} + 1''.46 = & 0.165623 \end{array}$$

Apparent $\alpha = 11^h\ 35^m\ 41^s.205$ Apparent $\delta = -\ 6^\circ\ 49'\ 41''.65$

which agree exactly with the Ephemeris.

Meridian Passage.

The mean time of transit at Greenwich is computed by (26) and (27) as in the case of the Moon. Thus

$$\begin{aligned} 1895,\ \text{Sept. } 17,\ \Theta &= 11^{h}\ 44^{m}\ 40^{s}.46 \\ \alpha &= 11\ \ 35\ \ 41\ .21 \\ \hline \alpha - \Theta &= -\ \ \ 8\ \ 59\ .25 \\ &= -\ 539^{s}.25 \end{aligned}$$

$$m = -\ 5^{s}.503 \quad \therefore\ 3609.856 - m = 3615.359$$

therefore

$$t_{m} = -\ \frac{539.25}{3615.359} = -\ .14915 \text{ hours}$$

the negative sign indicative that the transit takes place before mean noon of Sept. 17 or at

$$\text{Sept. } 16^{d}\ 23^{h}.85085 = \text{Sept. } 16\ 23^{h}\ 51^{m}.0$$

which also agrees with the Ephemeris.

Semidiameter and Horizontal Parallax.

On page 523 (Appendix) are given the semi-diameters of the planets as seen at certain distances; thus the semi-diameter of Venus at distance unity, *i. e.*, at the Earth's mean distance from the Sun, is 8″.546 with a probable error of ± 0″.086, hence it follows that at distance Δ, the

$$\text{semi-diameter} = \frac{8''.546}{\Delta}$$

For 1895, Sept. 17, we have

$$\begin{aligned} \log\ 8''.546 &= 0.9317639 \\ \log\ \Delta &= 9.4512787 \\ \hline 30''.23 &= 1.4804852 \end{aligned}$$

It is also evident that the horizontal parallax

$$= \frac{\text{Sun's equatorial Hor. Parallax}}{\Delta}$$

In the American Ephemeris for 1895, the Sun's mean equatorial horizontal parallax is taken equal to 8″.848 which, however, is too great by at least 0″.04.

$$\begin{aligned} \log\ 8''.848 &= 0.94685 \\ \log\ \Delta &= 9.45128 \\ \hline 31''.3 &= 1.49557 \end{aligned}$$

therefore the semi-diameter is 30″.2 and the equatorial parallax 31″.3.

The Transit Ephemeris for Washington.

From the Greenwich "Meridian Passage" we can easily obtain

an approximate time for the transit at Washington; thus the difference between the times of Greenwich transit on the 16 and the 17th of September is 6.1 minutes and the proportional part for $5^h\ 8^m\ 12^s$, the west longitude of Washington, is 1.3 minutes which being deducted from the time of transit on the 16th as the motion of the planet is retrograde, gives $23^h\ 49^m.7$ for the approximate date of the Washington transit and this is the date actually given in the Ephemeris on page 399. A more accurate value, however, must be found in order to compute the R. A. and Decl. at the time of transit at which date the R. A. must be equal to the sidereal time. Sept. $16^d\ 23^h\ 49^m.7$ Washington time = Sept. $17^d\ 4^h\ 57^m.9$ Greenwich time and for this date we have

$$\begin{array}{rrrr} \alpha = & 11^h & 35^m & 13^s.873 \\ \Theta = & 11 & 35 & 10\ .079 \\ \hline \alpha - \Theta = & & + & 3\ .794 \end{array} \quad \text{and } \Delta\alpha = -0''.0916$$

then by (27) $\tau = +0.06296m$

therefore the true time of the Washington transit is Sept. 16 $23^h\ 49^m.763$ and $\alpha = \Theta = 11^h\ 35^m\ 13^s.867$ which proves the accuracy of the work.

The declination, semi-diameter and parallax are now interpolated for this date. The sidereal time of the semi-diameter passing the meridian is found by (28) as in the case of the Moon.

(TO BE CONTINUED.)

SPECTROSCOPIC STUDY DURING THE APPROACHING SOLAR ECLIPSE.*

"We now come to the spectroscopic part of the attack of the problems of the total solar eclipse. The spectrum of every prominence, every part of the visible chromosphere, and of as many regions of the corona as possible is to be observed or photographed, in order that the duty of fully recording the phenomena shall be faithfully accomplished. It is true that the chromosphere and prominences can be investigated without an eclipse, but it would be unwise completely to neglect them in the belief that we perceive everything connected with them in our daily observations. At the same time, as the corona cannot yet certainly be observed at all except during an eclipse, and the lower reaches of the chromo-

* Extract from an article in *Knowledge* for June, 1896, by A. Fowler, of England.

sphere only very imperfectly, it is to these features that attention will be chiefly directed.

For recording the spectroscopic appearances, instruments of two forms are employed—those which are provided with slits, and those which utilize the eclipsed Sun itself as a virtual slit in the form of a ring.

The ordinary slit spectroscope may be used in either of two ways. It may be employed as an integrating spectroscope by simply directing the collimator to the Moon's centre, or as an analyzing spectroscope by placing the slit in the focal plane of a telescopic objective or condenser. In the first case the spectra of corona, prominences and chromosphere will all be superposed, so that in the absence of other evidence the spectra of the different parts could not be separated. The use of a condensing lens enables the observer to localize some particular region of the corona upon the slit, and its spectrum may then be studied apart from that of its neighbors.

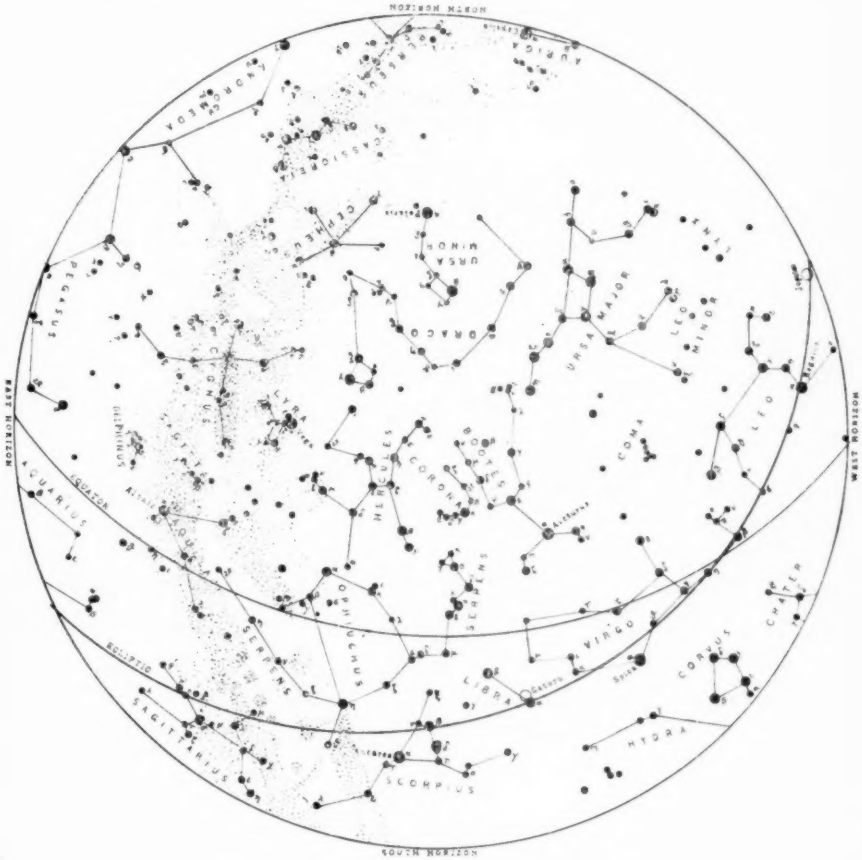
Spectroscopes without slit or collimator were first employed for eclipse observation by Respighi and Lockyer, in 1871. The principal of this method is very simple. In an ordinary spectroscope the function of the collimating lens is to render parallel the rays proceeding from the slit; and the "lines" which one usually associates with spectra are simply images of the slit. If the ordinary slit be replaced by a circular one the spectrum lines become spectrum rings; indeed the shape of the slit in all cases is reproduced in the "lines." The rays proceeding from the Sun are already parallel, so that a collimating lens is superflous, and the eclipse itself is at once the source of light and the slit. The eclipsed Sun is in reality a number of independent slits: one—a complete ring—corresponding to the corona, and others of irregular form corresponding to the different parts of the chromosphere and prominences. Each "line" in the spectrum of a prominence is represented by a picture of the prominence, and if different vapors are unequally distributed these images will differ.

When the slitless spectroscope is employed for photography it becomes a "prismatic camera," and takes the form of a large prism placed in front of the objective of a photographic telescope. As a single exposure gives the spectrum of every part of the solar surroundings, the prismatic camera provides a very complete record of the spectroscopic appearances during an eclipse. For a considerable interval before and after totality the sky illumination is sufficiently reduced to show the chromosphere spectrum near the cusps of the crescent Sun, and very valuable photo-

graphs may therefore be taken out of totality. Incidentally it turns out that the prismatic camera is the best possible instrument for photographing the solar prominences."

THE PLANETS AND CONSTELLATIONS FOR JULY 1896.

Mercury will be at greatest western elongation 21° 25′ from the Sun on July 3, and so will be visible in the east in the morning at that time. During the latter half of the month Mercury will be near the Sun, reaching superior conjunction July 31 at noon.



THE CONSTELLATIONS AT 9^h P. M., JULY 1, 1896.

Venus will be invisible during this month, because she is behind the Sun. Superior conjunction occurs July 8.

Mars is on the meridian about 7 o'clock in the morning, in north declination 10° +. An observer may get a fair view of the planet toward the east between 3 and 4 o'clock A. M. The diameter of the planet's disk is however only about 8″, the distance being still greater than that of the Sun, so that one must not expect to see much of detail in the surface markings. Mars will be in conjunction with the Moon, about 7° south of the latter, on July 4 at $5^h\ 58^m$ P. M. Central Standard time.

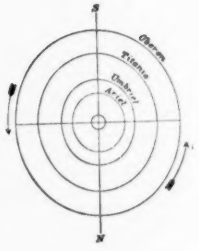
Jupiter is too far west for observations of any value, though he may be seen low down in the west for some time after sunset. Jupiter and the new Moon will be in close conjunction on the morning of July 12.

Saturn has passed the best position for observation for this year, but may yet be quite satisfactorily viewed between 8 and 9 o'clock in the evening. During this month Saturn will be almost stationary between the two stars of Libra, whose positions relative to the planet must have been noticed by the most casual observer during this summer. Toward the end of the month the easterly motion of the planet will begin to be perceptible. Saturn will be in conjunction with the Moon, about 8° to the north of the latter, on the evening of July 18 at $6^h\ 51^m$ Central Standard time.

Uranus is in Libra, southeast of Saturn, in R. A. $15^h\ 13^m$ and Decl. — 17° 40′. On July 28 Uranus reaches the western end of the loop in its annual motion, in R. A. $15^h\ 12^m\ 16^s$, and Decl. — 17° 36′, and after that time will move toward the east among the stars. Conjunction with the Moon occurs July 19 at $7^h\ 7^m$ A. M., when the planet will be 5° 42′ north of the Moon's center.

Neptune is not in position for observation.

The Satellites of Uranus.



ARIEL.

North.		South.	
July 2	8.5 P. M.	July 1	2.2 P. M.
5	9 0 A. M.	4	2.7 A. M.
7	9.5 P. M.	6	3.2 P. M.
10	10.0 A. M.	9	3.7 A. M.
12	10.5 P. M.	11	4.2 P. M.
15	11.0 A. M.	14	4.7 A. M.
17	11.5 P. M.	16	5 2 P. M.
20	12.0 M.	19	5.7 A. M.
23	12.5 A. M.	21	6.2 P. M.
25	1.0 P. M.	24	6.7 A. M.
28	1.5 A. M.	26	7.2 P. M.
30	2.0 P. M.	29	7.7 A. M.
		31	8.2 P. M.

TITANIA.

North.		South.	
July 7	7.4 A. M.	July 2	10.9 P. M.
16	12.5 "	11	3.9 "
24	5.5 P. M.	20	8.9 A. M.
		29	2.0 "

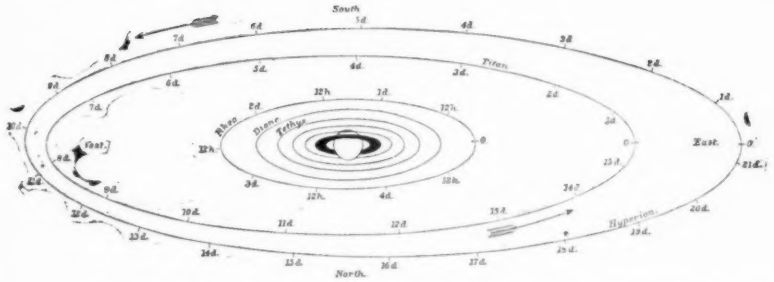
OBERON.

July 2	8.0 P. M.	July 9	1.6 P. M.
16	7.3 A. M.	23	12.9 A. M.
29	6.4 P M.		

UMBRIEL.

North.		South.	
July 3	8.2 A. M.	July 5	9.9 A. M.
7	11.7 "	9	1.4 P. M.
11	3.1 P. M.	13	4.9 "
15	6.6 "	17	8.4 "
19	10.1 "	21	11.8 "
24	1.6 A. M.	26	3.3 A. M.
28	5.0 "	30	6.8 "

Saturn's Satellites.



[In the diagram the points marked 0 are those of eastern elongation as seen in an inverting telescope, and those marked 1d, 2d, etc. represent the positions of the satellites at intervals of one day, two days, etc. after the times of eastern elongation. E = east elongation. I = inferior conjunction (south of planet). W = west elongation. S = superior conjunction (north of planet).]

MIMAS.

		h		
July	2	1.5	A. M.	E
	3	12.1	"	E
	3	10.7	P. M.	E
	4	9.3	"	E
	5	7.9	"	E
	10	1.7	A. M.	W
	11	12.3	"	W
	11	10.9	P. M.	W
	12	9.6	"	W
	13	8.2	"	W
	14	6.8	"	W
	19	11 9	"	E
	20	10.5	"	E
	21	9.1	"	E
	22	7.7	"	E
	28	12.2	A. M.	W
	28	10.8	P. M.	W
	29	9 4	"	W
	30	8.0	"	W

ENCELADUS.

		h		
July	1	8.4	A. M.	E
	2	5.3	P. M.	E
	4	2 2	A. M.	E
	5	11.0	"	E
	6	7.9	P. M.	E
	8	4.8	A. M.	E
	9	1 7	P. M.	E
	10	10.6	"	E
	12	7.5	A. M.	E
	13	4.4	P. M.	E
	15	1.3	A. M.	E
	16	10.2	"	E
	17	7.0	P. M.	E
	19	3.9	A. M.	E
	20	12 8	P. M.	E

ENCELADUS CONT.

		h		
	21	9.7	P. M.	E
	23	6.6	A. M.	E
	24	3.5	P. M.	E
	26	12 4	A. M.	E
	27	9.3	"	E
	28	6.2	P. M.	E
	30	3.1	A. M.	E
	31	12.0	M.	E

TETHYS.

		h		
July	2	9.2	P. M.	E
	4	6 5	"	E
	6	3.8	"	E
	8	1.1	"	E
	10	10.4	A. M.	E
	12	7.8	"	E
	14	5.1	"	E
	16	2 4	"	E
	17	11 7	P. M.	E
	19	8.9	"	E
	21	6 2	"	E
	23	3.5	"	E
	25	12 8	"	E
	27	10.1	A. M	E
	29	7.4	"	E
	31	4 7	"	E

DIONE.

		h		
July	2	1.4	A. M.	E
	4	7.1	P. M.	E
	7	12.8	"	E
	10	6.5	"	E
	13	12 2	A. M.	E
	15	5.9	P. M.	E
	18	11.6	A M.	E
	21	5.2	A. M.	E

DIONE CONT.

		h		
July	24	10.9	A. M.	E
	26	4.6	P. M.	E
	29	10.3	A. M.	E
	31	4 0	P. M.	E

RHEA.

		h		
July	3	11.0	A. M.	E
	7	11.3	P. M.	E
	12	11.7	A. M.	E
	17	12.1	"	E
	21	12.5	P. M.	E
	26	12.9	A. M.	E
	30	1.3	P. M.	E

TITAN.

		h		
July	5	4.5	A. M.	E
	9	1.4	"	I
	13	5.5	"	W
	17	6 6	"	S
	21	1.5	"	E
	24	10 4	P. M.	I
	29	2.5	A. M.	W

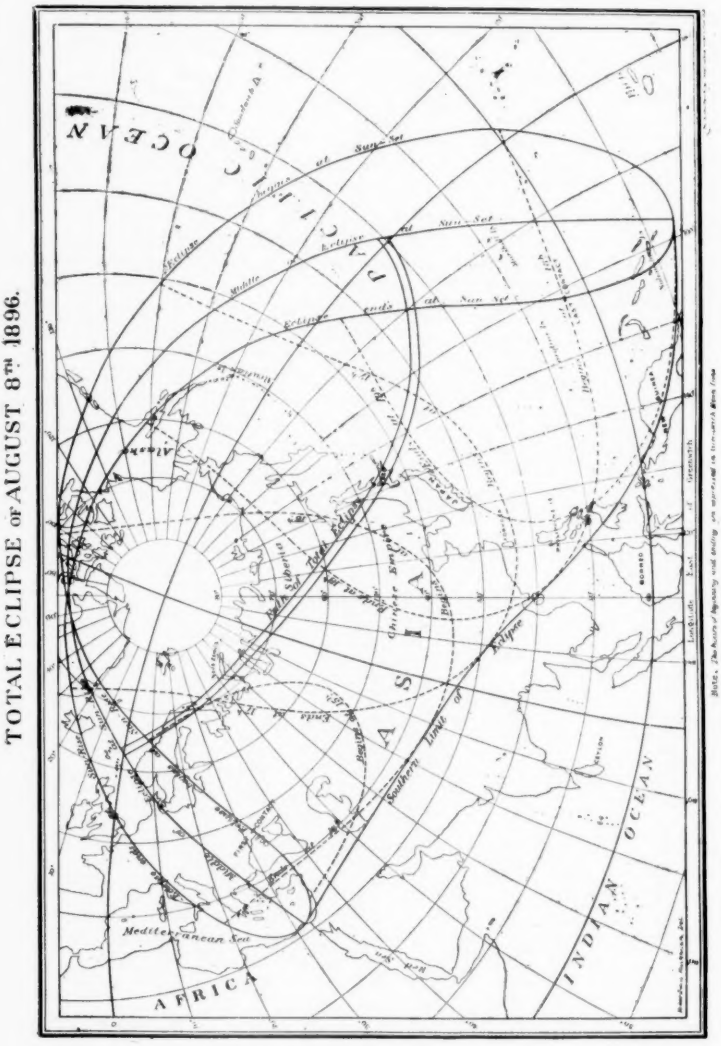
HYPERION.

		h		
July	4	1.7	P. M.	S
	10	7.6	A. M.	E
	16	11 5	"	I
	21	6.6	"	W
	25	7.1	P. M.	S
	31	1.1	"	E

IAPETUS.

		h		
July	1	9.5	A. M.	I
	21	3.5	P. M.	W
Aug.	10	7.5	"	S

The Total Solar Eclipse, Aug. 8-9, 1896.—This eclipse while not visible at all in the United States, is yet likely to be witnessed by many of the readers



of POPULAR ASTRONOMY, since the line of totality passes across a region easily accessable to summer tourists. The accompanying chart taken from the *Ameri-*

can Ephemeris shows the path of total eclipse, beginning at sunrise in the North Atlantic ocean, passing across the northern part of Norway and the Island of Nova Zembla, thence diagonally across Siberia and the Japanese Island Jezo, ending at sunset in the Pacific ocean. The most popular place of observation for Americans and Europeans will be on the northeast coast of Norway, probably at Vadsö on the Varanger Fjord, and a number of excursions have been arranged to this place and to others on the west coast of Norway. The voyage around the coast of Norway into the region of the "Midnight Sun" will present opportunities for viewing some of the grandest, most rugged, mountain scenery to be found anywhere, although the destination reached, save for the eclipse, would be void of attraction. The following description extracted from notes in the April number of the Journal of the British Astronomical Association may be of interest to our readers.

"The Varanger Fjord runs inland W. N. W.; the land lying north of it is called Varanger Peninsula, and that to the south of it South Varanger. All the land is fjeld (mountainous land, highland,) but it rises nowhere to any great height. The Varanger Peninsula is a plateau which, on its western border attains a height of 2,200 feet, and on its southern about 1,500 feet. The plateau is, however, not quite level, but presents such long gentle undulations as are seen on the open ocean in calm weather. The permanent population, which keeps to the sea coast, has here and there some outlying fields in the open parts of the valley near the sea.

"With the exception of these and the neighborhood of the settled places, the whole region consists of rolling mountain tops, practically unknown to the civilized world. It can, according to all that we know of it, be described as a wilderness of rocks, a stony desert covered here and there with reindeer moss, and some swampy places where there thrives a scanty vegetation of green plants. About the center of the penninsula are some large lakes full of fish, which only a few Norwegians have visited."

The inhabitants are Norwegians, Laps and Fins, "the greater part of them living on the seashore, poor fishermen and farmers, who grow a little hay for their cattle and a few potatoes for themselves. There are no cereals in this northerly province. Many of the inhabitants live in wretched earth huts, which they share with their cattle." In Vardö and Vadsö there are small second-class hotels at which the charges are about 5s to 6s a day.

The Sun will rise only about 14° above the horizon during the eclipse at Vadsö and the chances for cloudy weather are comparatively large. The more favorable stations are in the interior of Siberia but are practically inaccessible to observers In Japan the conditions are quite good, and we may confidently expect good results from the several parties which will be stationed there.

Chart of the Stars in the Vicinity of the Sun.—During the two minutes of totality the principal stars will become visible to the naked eye. The accompanying chart shows the stars in the vicinity of the Sun on Aug. 9. It will be noticed that the Sun is then in Leo and that the planets Jupiter, Venus and Mercury are near together in the same region.

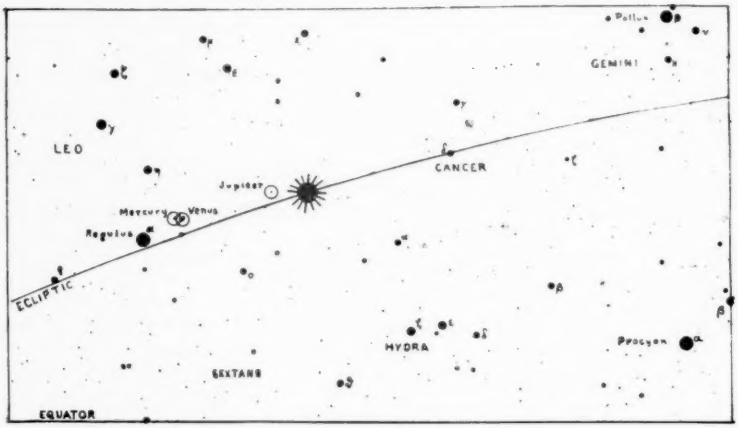


CHART OF THE SKY IN THE VICINITY OF THE ECLIPSED SUN.

Observing Stations.—The following list for the solar eclipse of August 8 9, 1896, is given in the last number, April 27, 1896, of the *Journal of the British Astronomical Association* by Mr. A. C. D. Crommelin:

1. Near *Bodo*, nearly certain to be occupied by numerous amateurs.

2. Near *Enontekis*, Finland.—To be occupied by an expedition sent by the Russian Astronomical Society, who propose to photograph the corona by several clock-driven cameras, and also to time the contacts.

Professors Glasenapp and Vuchikhovsky will also occupy a station in this neighborhood.

3. *Varanger Fjord.*—To be occupied by the British Astronomical Association expedition, and also by one of the official expeditions sent by the joint committee of the Royal Society and Royal Astronomical Society. There will also, doubtless, be numerous amateurs in this neighborhood.

4. *Nova Zembla.*—To be occupied by expeditions representing the Russian Academy of Sciences, and the Kasan Society of Naturalists.

5. *Mouth of Obi.*—A second expedition of the Russian Astronomical Society will photograph the corona here with fixed cameras.

6. *Olekminsk on Lena.*—A third expedition of the Russian Astronomical Society will photograph the corona here with the long focus lens (Schaeberle's method). They also propose to photograph the spectrum of the corona with two spectrographs. A comparison will be made of the coronal and helium spectra. Professor Voznesensky, Director of the Irkutsk Observatory, will make meteorological observations here. Time determinations will also be made.

7. *On the Amur River.*—This station will be occupied by an expedition from Pulkova Observatory.

8. *American Expeditions to Yezo.*—The programmes of these parties are very complete. Professor Schaeberle will again employ his long focus lens for large scale photographs of the corona.

9. *English Expeditions to Yezo.*—The joint committee of the Royal Society and Royal Astronomical Society will send a second expedition to Kushiro, on the

east coast of Yezo. Both their expeditions are provided with coelostats, which will give fixed images of the corona for photographic purposes.

There will, doubtless, be other expeditions, both English and Japanese, in the Island of Yezo.

What is to be Studied During Totality.—The time of totality in this eclipse is very short, less than two minutes, and no one observer can accomplish very much in this time, but by proper division of the work something valuable can be determined on each of the following points:

1. The times of four contacts.
2. The form of the corona and prominences by means of photography with large and small cameras, long and short exposures.
3. Spectroscopic observations both visual and photographic of the corona and prominences and the reversing layer.
4. Photometric observations of the brightness of the different parts of the corona.
5. Observations with the polariscope to determine the nature of the coronal light.
6. Attendant phenomena:
   - *a.*—Approach of the lunar shadow.
   - *b.*—Colors and illumination during totality.
   - *c.*—The shadow bands.
   - *d*—Meteorological observations.
   - *e.*—Effect of the eclipse on plants and animals.
   - *f.*—Baily's beads.
   - *g*—How long before and after totality can the corona be seen?
   - *h.*—Illumination of the Moon's disk.
   - *i.*—Appearance of the sky; what stars, planets and comets are visible?

What various individuals are planning to do is interestingly told in the article on page 28.

We may add that the Lick Observatory has sent an expedition to Japan under the direction of Professor J. M. Schaeberle. The program of the expedition will be wholly photographic. Professor Schaeberle will make large-scale photographs of the corona with a lens of forty-foot focus, on the plan which was so successful in Chile in 1893; and smaller pictures (some on standardized plates) will be taken with the five-inch Floyd photographic telescope.

Mr. Burchhalter, Director of the Chabot Observatory, Oakland, will photograph the corona with a special telescope, of four inches aperture and twenty feet focus, and apparatus of his own design for giving different exposures to the inner and outer portions of the corona at the same time so that both parts may be shown on the same picture. Dr G. E. Shuey and Mr. Louis C. Masten have volunteered to accompany the expedition at their own cost, to serve as assistants to Professor Schaeberle and Mr. Burckhalter.

The United States Government sends no expedition; but Professor D. P. Todd, astronomer at Amherst College, has organized a private expedition and will take the same apparatus which he took to Africa in 1893. This was all photographic consisting of several cameras of different sizes and focal lengths, driven by the same clock-work, the exposures and changes of plates all being made automatically. The expense of this expedition is borne by Mr. Arthur James Curtis who conveys the party to Japan in his schooner yacht Coronet. The yacht carrying the instruments sailed from New York round Cape Horn in the spring and meeting the party at San Francisco set sail for Japan early in June.

Ten New Variable Stars.—The following list of new variable stars includes, as described below, three whose variability was discovered or suspected elsewhere and has been confirmed at this Observatory. The successive columns give the name of the constellation, the designation in the Durchmusterung Catalogues, the approximate right ascension and declination for 1900, the number of plates examined, the magnitude when brightest and when faintest as derived from the photographic charts, and the authority for the variation, the letters H. C. O. indicating that the variation was found at this Observatory.

Constellation.	Designation.	R. A. 1900	Decl. 1900	No. Plates.	Magn.		Authority.
					Br.	Ft.	
	°	h m	° ′				
Horologium.	....	2 22.4	− 60 0	21	9.7	<12.7	H. C. O.
Canis Minor	+ 5 1797	7 43 4	+ 5 40	42	10.3	11.3	H. C. O.
Pyxis.....	− 24 7693	9 0.7	− 24 41	13	8.9	11.1	Thome.
Hydra.....	− 22 7652	9 46.4	− 22 32	32	8.2	10.1	H. C. O.
Centaurus....	.....	11 16.1	− 61 20	70	9.2	<12.9	H. C. O.
Libra.....	− 19 4047	15 6 5	− 19 25	....	.....	.....	H. C. O.
Scorpius.....	− 35 11829	17 35.7	− 35 12	31	10.7	11 6	H. C. O.
Cor. Austr...	− 37 12782	18 34.3	− 37 56	67	8.9	<11.8	H. C. O.
Sagittarius..	− 33 14076	19 10.0	− 33 42	89	6.1	<11.3	Markwick
Sculptor.....	− 30 19448	23 3.7$_s$	− 30 41	47	8.0	8.9	H. C. O.

The first star, R. A. $2^h\ 21^m\ 39^s$, Decl. − 60° 8′.0 (1875), has a period somewhat greater than 300 days.

The second star, + 5° 1797, was faint on two plates taken in 1886, and on the photographs taken since then shows variations which though small appear to be real.

The third star, − 24° 7693, was suspected of variability by Thome. (Annals Cordoba Observatory, Vol. XVI, p. 38). As he distinguished this star by an exclamation mark photographs of it, and of six others similarly marked, were examined here by Miss E. F. Leland and the variability of this star was established.

The fourth star, − 22° 7652, was found by Miss L. D. Wells from a comparison of two chart plates in her search for stars having large parallaxes, proper motions, or variations in light. This star has been suspected of variability by Espin and Thome. Their names, however, are not included in the above table since almost all stars have been suspected of variability, and attempts to confirm suspected variables have failed in a large number of cases. It would obviously be unfair when an astronomer publishes a long list of suspected variables to regard him as the discoverer of any which on later evidence may prove to be variable. It is extremely improbable that the light of the Sun, or of any star, is absolutely constant although the change is in the great majority of cases beyond our present means of measurement. If the distinction between real and suspected variability is not maintained the person first stating that all stars are variable might claim the discovery of all variables subsequently found. It will be seen that this star stands on a wholly different basis from the preceding star since in that case the variability suspected by Thome was the reason for the further examination of this object. This star is − 22° 2739 in the Bonn Southern Durchmusterung. Its spectrum was found to be of the fourth type by Dunér.

The fifth star, R. A. $11^h\ 15^m\ 1^s$, Decl. − 61° 11′.4 (1875), has maxima represented by the formula J. D. 2,411,100 + 162E. The next maximum will accordingly occur on October 21, 1896.

The sixth star, − 19° 4047, 9 Libræ, appears in four of the catalogues of

stars measured with the meridian photometer. In Vol. XIV measures on seven nights gave the magnitude 4.87. In Vol. XXIV Table I, three nights gave the magnitude 4.36. In Vol. XXIV Table IV, three nights gave the magnitude 5.02, and in Vol. XLIV, unpublished, three nights gave the magnitude 4.37. The discordance is so great as compared with that of other stars contained in these catalogues that variability of the star seemed to the writer the only reasonable explanation. Accordingly, visual observations were at once undertaken with the meridian photometer, and also by Argelander's method. By the latter method, Mr. Wendell soon confirmed its variability finding it two grades fainter than δ Libræ on May 19, and two grades brighter than the same star on June 1, 1896.

The eighth star, — 37° 12782, has an approximate period of 136 days.

The ninth star, 33° 14076, is a very remarkable object. It was one of a list of 42 stars suspected of variability sent here for examination by Colonel E. E. Markwick of Gibraltar. A report was sent to him that an examination of several photographs failed to show any sign of variability. A few days later an object having a peculiar spectrum was discovered by Mrs. Fleming. All the plates of the region were examined and its variability established. It was about to be published in Circular No. 6, when it was found to be identical with the star of Colonel Markwick. It was accordingly reported to him for announcement but he has kindly authorized its publication here. The photographs show that on eight nights in the summer of 1889, on six nights in 1890, on six nights in 1891, on five nights in 1892, on twelve nights during April, May, June and July of 1893, the variation of light of this star was comparatively small and irregular. Colonel Markwick's first two observations on July 14 and 19, 1893, showed it of the seventh magnitude and a little brighter than the adjacent star — 33° 14068. In August he found it fainter than this star, and by September 12 it was invisible and below the ninth magnitude. A photograph taken here on September 11, showed that it must then have been fainter than the magnitude 9.6 and on October 23, fainter than 11.3. Photographs taken on April 30, May 30, July 8, August 7, August 10, September 12, September 15, November 12 and November 13, 1894, gave the magnitudes 10.9, 10.3, 9.4, 8.6, 8.3, 7.5, 7.6, 6.4 and 6.4 respectively, thus showing a nearly regular increase to its normal brightness, which it retained with irregular variations on twenty-seven nights in 1895. Its magnitude on June 2, 1896 was 6.7. Observations by Colonel Markwick, beginning on August 20, 1894, lead to a similar result. The spectrum of this star is peculiar, and contains bright lines which show evidence of change.

The variation of the tenth star, — 30° 19448, is small and irregular.

The spectra of the first, fifth, eighth and probably the tenth stars are of the third type, having also the hydrogen lines bright. The second and seventh have spectra of the fourth type. These six variables were found by Mrs. Fleming in her regular examination of the Draper Memorial photographs.

A large number of observations have been made with the meridian photometer to determine the forms of light curve of stars of the Algol type. S Antliæ has hitherto been regarded as belonging to this class and is of interest from the shortness of its period; $7^h\ 46^m.8$, and since it was said to retain its full brightness for less than half of the time. It is difficult to reconcile the last condition with the theory that the variation is due to a dark eclipsing body. One hundred and seventy-seven measures, each containing sixteen photometric settings on S Antliæ were made with the meridian photometer and give eight normal points. A smooth curve with only two points of inflection can be drawn through these normal points, the greatest deviation being 0.02 magnitudes. From this it ap-

pears that S Antliæ is not a star of the Algol type, that its light is continually changing, and that it belongs to the class of variables of short period like δ Cephei and η Aquilæ. An interesting feature of this curve is that the time of increase occupies 0.62 of the entire time of variation, the increase of light being slower than the diminution.

U Pegasi appears to be second in this respect, since, according to the *Astronomical Journal*, Vol. XVI, p. 108, its time of increase is 0.55 of the entire time, and that of other short period variables varies from 0.20 to 0.33. On the other hand, the time of increase is about 0.17 for No. 18 of the variables discovered in the cluster Messier 5. See *Astron. Nach.*, Vol. 140, p. 285.

The star β Lyræ is commonly regarded as a variable of short period of the same class as the above. Observations of its spectrum, however, show that two or more bodies, revolving round each other, are present. The light curve found by Argelander may be closely represented by assuming that the primary minimum is caused by the eclipse of the brighter body by the fainter, and the secondary minimum by a similar eclipse of the fainter body by the brighter. This star should therefore be taken from the class of ordinary short period variables and included among the stars of the Algol type.

Mr. Backhouse calls attention to his announcement in "The Observatory," Vol. XVII, p. 402, of the variability of $+ 0° 939$, announced in the *Astrophysical Journal*, Vol. 2, p. 198, and to his observations which indicate a period of not more than a year. Variability also suspected by Espin.

The variable star, R Microscopii, is identical with $- 29°$ 17235.

EDWARD C. PICKERING.

Harvard College Observatory, Circular No. 7.
June 5, 1896.

New Asteroids.—Two new asteroids were found in May. They are both of the twelfth magnitude and were found by their trails on photographic plates exposed by Mr. Charlois at Nice and Professor Wolf at Heidelberg. They are designated temporarily as CS and CT The asteriod CD, found by Wolf 1895, Oct. 13 will be designated as number 408. Names have been assigned as follows:

No. 337, discovered by Charlois, 1892, Sept. 22, *Devosa*.
No. 339, " " " 1892, Sept. 25, *Boudrosa*.
No. 340, " " Wolf, 1892, Sept. 25, *Eduarda*.

COMET NOTES.

Re-discovery of Brook's Periodic Comet (1889 v).—A telegram received June 22 announces the discovery of Brook's comet (1889 v) by Javelle at the Observatory at Nice. The observed position of the comet June 20.575 was R. A. $22^h\ 25^m\ 38^s.0$; Decl., $- 18°\ 33'\ 59''$. This agrees well with the computed place given some time ago by Mr. Chas. Lane Poor, who calculated the definitive elements from the observations of 1889. The correction to his ephemeris is in R. A. $- 25^s$; and in Decl. $- 2'.6$.

Orbit of Comet *b* 1896 (Swift).—Mr. R. G. Aitken publishes new elements of this comet in the last number (377) of the *Astronomical Journal*. These depend upon three normal places dated April 18.5, April 30.0 and May

25.5, fifteen observations in all. The residuals for the middle place are very small.

ELEMENTS.

$$
\begin{aligned}
T &= \text{Greenwich M. T., April } 17.64665 \\
\Omega &= 178^\circ\ 15'\ 58''.1 \\
i &= 55\ \ 34\ \ 16\ .0 \quad 1896.0 \\
\omega &= 1\ \ 44\ \ 7\ .6 \\
\log q &= 9.753114
\end{aligned}
$$

EPHEMERIS.

		App. R. A.			App. Decl.		log r	log Δ	Brightness.
		h	m	s	°	′			
July	2.5	20	25	26	+ 68	25.1	0.2029	0.1088	0.030
	4.5	20	17	33	67	43.7			
	6.5	20	10	11	66	59.8	0.2194	0.1190	0.027
	8.5	20	3	19	66	13.4			
	10.5	19	56	56	65	24.9	0.2351	0.1290	0.024
	12.5	19	51	3	64	34.2			
	14.5	19	45	37	63	41.6	0.2501	0.1390	0.021
	16.5	19	40	37	62	47.2			
	18.5	19	36	3	+ 61	51.2	0.2645	0.1492	0.019

The comet is now less than one-thirtieth as bright as when discovered in April but ought to be visible in the large telescopes.

QUERIES WITH SHORT ANSWERS.

132. Kindly direct me so that I may find Uranus with the small telescope, and distinguish the planet from neighboring stars. J. W. H.

Answer: For the general position of the planet Uranus, see our notes from month to month. There are two ways by which the planet is recognized by those who are not accustomed to observe it with a telescope. The first is, by noticing carefully the appearance of its disk. It is planetary and not stellar. The planet does not twinkle like a star. This is plainly noticeable in a good, small telescope if a bright star is viewed in comparison with it. Authorities differ in regard to the color of the planet's light. Some say it is greyish-blue, as for example, Capt. Wm. Noble "Hours with a three-inch telescope," p. 79. Others hold that it is sea-green, Young's General Astronomy, p. 367.

Another way of determining the planet is by noticing its motion, with reference to neighboring stars, which can be detected after a few days of watching.

133. To whom shall I apply for telescopic announcements of astronomical discoveries? W. J. B.

Answer: Harvard College Observatory, Cambridge, Mass., is the central station in the United States for the distribution of telegraphic information of astronomical discoveries. Write to Professor E. C. Pickering, Director of the Observatory, or to John Ritchie, Jr., Cambridge, Mass., who is in immediate charge.

GENERAL NOTES.

This number begins the fourth volume of this publication which bears date for July instead of September as heretofore. The change in time for the beginning of the volume is made for two reasons: First, because apparently, a majority of our readers prefer the beginning of the calendar year as the time for subscription payment and hence the time when subscriptions should begin; and secondly because we have useful matter for publication in hand that should not wait two monnhs for publication. This and succeeding volumes will consist of *ten numbers*, of about 580 pages, each, as heretofore the successive issues being monthly until number one of Volume VII has even date with Jannary, which will occur at the beginning of the year 1899. After that date the volumes will probably be annuals, as was our custom with Astronomy and Astro-Physics.

We have taken the trouble and incurred the expense of writing to all whose subscriptions are due for the ensuing volume, asking for prompt instructions concerning orders for continuance, with the added suggestion that, if remittances accompany orders, the publisher will thereby be favored, because he pays nearly all bills in advance so as to have the advantage of cash purchases. The response to this suggestion is already quite general and gratifying. It is also thought best not to send our publication beyond the time for which it has been previously ordered, because we do not wish to mail a single copy where it is not wanted, and we cannot be presumed to know what the desire of subscribers is without specific orders. Will our friends please give prompt attention to this matter?

The New Astro-Photography.—In addition to what was said last month, page 536, it now may be added, that the photographs and manuscript of Mr. David E. Packer has been submitted to some American astronomers and astrophysicists for opinions of their true value. Professor C. A. Young's thought of the matter, written June 6, is helpful and considerately just in our view. It is briefly as follows:

"The photograph of Aug. 28th, 1895, certainly looks very coronal; and if instead of a single photograph we had half a dozen or so made in close succession, and showing a substantial agreement in the details of streamers, "bombs," etc., the evidence would be nearly conclusive that the picture was really a representation of something at the Sun: as it is, one is at liberty to suppose that it is due to some action on the surface of the plate produced by the heating of the metal film near its surface, if the film *is* near the plate, in respect to which Mr. Packer is not explicit. Or if not due to simple heating, one can think of other possible actions upon the metallic film which would be likely to affect the plate under it. The experiment ought to be made simultaneously with different cameras, plates, and interposed films of metal; and I think it important that longer focal distances should be used, giving a reasonable diameter to the Sun's disc. At the distance of five inches the image would be only $\frac{1}{20}$ of an inch in diameter, or just the size of the pin-hole that was used instead of a lens, Of course under such conditions no definition is possible.

The paper print (Sept. 25th, 1895) does not look like a corona any more than it does like a dog's head.

Of course all the discussion with reference to the relation between the spots and the coronal streamers shown on the plates is out of order until the real char-

acter of the photographs is settled. If Mr. Packer has several pictures that agree in showing what he claims he should show them at once."

It might be added, further, that Mr. Packer should be more explicit as to the character and thickness of the metallic film used by him, and the distance between it and the sensitive plate to enable others to verify his results as readily as possible.

The Astrographic Chart of the Heavens.—Professor Harold Jacoby, of the Observatory at Columbia College, in *Science*, June 19, summarizes the work of the international committee having in charge the work of Astrographic Chart of the Heavens, as follows: "The Committee met in Paris on May 11, and the following days. The proceedings related principally to the technical details of of the work. The reports of the directors of the various observatories taking part in the photographs, were, however, of considerable public interest. It appears from these reports that the series of plates from the measurement of which a Catalogue of all the stars down to the eleventh magnitude has been practically completed, at nearly all the participating observatories. The second series of of plates, which are to be used simply as a chart and which will include stars several magnitudes fainter than the smallest ones admitted to the great Catalogue, is also well advanced. These chart plates require a much longer exposure than the Catalogue plates, and for this reason it is not possible to finish them as quickly as the others.

The measurement of the Catalogue plates has progressed with satisfactory rapidity at several of the observatories, so that we may expect the first installment of the Catalogue within a very few years. The final completion of it will perhaps require twenty-five or thirty years. The probable error of the final Catalogue positions will be about one-tenth of a second of arc in either coördinate."

The Metric System.—Renewed interest seems to be felt in educational circles concerning the general adoption of the metric system of weights and measures in the United States.

Scientific societies very generally have been active of late in urging congress to pass a law making the use of the metric system compulsory. As a result of this wide-spread belief that the time has come for such a step to be taken in the United States, about three months ago, a report was made, from the committee on coinage, weights and measures in the House of Representatives, strongly favoring the adoption of the metric system and the requirement of its general use as soon as consistent with the best interests of the various kinds of business affected by the change. That report sets out clearly the two-fold advantage of the metric system. The first is that the system is international in character, and is now almost universally in use among civilized nations. It is now the system of Europe except in England, Russia and Denmark. During the last year this matter has been under consideration in the House of Commons in England, and the committee having it in charge have recommended, with a single dissenting vote, that the metric system be at once legalized for all purposes and that after a period of two years its use be made compulsory. The other reason is the metric system, from its decimal character, is convenient and economical in practcal use. The reason is so evident, from a moment's thought, that the wonder is that the system has not been adopted long ago. The single consideration of time-saving in business and in school life by the use of a decimal system is enough to convince anybody that ordinary methods of calculation are most extravagantly wasteful in time and energy.

The objections to the metric system are, first, that the length of the meter has not yet been accurately determined. The brief answer to this obstacle is, that, although not a perfect standard, it is more perfectly determined, probably than any other, and that no absolute standard of length can be obtained from any known method or source of measurement. For a long time yet, in the nature of the case, absolute standards are an imposibility in any thing.

The chief objection, however, comes from the unwillingness of people generally to give up old and familiar methods for those that are new. There is no reason in this, and it is useless to try to combat such a position with arguments. The thing to do, in our judgment, is to make provision, as soon as it can be done wisely, for the compulsory adoption of the metric system of weights and measures and then uniformity of use will speedily follow.

New Divisions in the Rings of Saturn.—In April last Mr. E. M. Antoniadi at Juvisy, France, saw three divisions in the middle bright ring of Saturn with a 9¾ inch equatorial, magnifying some 300 diameters. "The first and darker of these objects lies nearly midway between the Cassini division and the crape ring, somewhat nearer the crape ring very likely." The other divisions lie on either side the first and were very difficult, being only glimpsed in the best seeing. The fact that this observer did not at the same time see the Encke division in the outer ring, makes us a little suspicious of the observation, but it is quite possible that these divisions periodically open and close with the revolution of the different parts of the rings. Mr. C. Roberts at Aberdeen, Scotland, saw the Encke division distinctly a few days later than the observation at Juvisy. There have been earlier observations of minute divisions in the middle ring but none that could be set down as positively identified by subsequent observations or measures.

Dr. C. N. A. Krueger.—Recent foreign papers contain field accounts of the death of the lamented Dr. Carl Nicolaus Adalbert Krueger which occurred, at Kiel, April 21, 1896.

Dr. Krueger was born at Marenburg, West Prussia, in 1832. He took Academic study at Elbing, Wittenberg and Berlin, after which at the age of 21 he was appointed assistant at the Bonn Observatory, under Argelander. Schönfeld was associated here with young Krueger in the work which is now known as the "Durchmusterung."

In 1862 Mr. Krueger became Director of the Helsingfors Observatory and while there in 1869 to 1876 he gave attention to the meridian observation of the Zone, + 55° to + 65°, for the Star Catalogue of the Astronomical Gesellschaft. In 1877 he was given the Directorship of Gotha Observatory, where the same work was continued with the same instrument.

By the aid of the Heliometer, while at Bonn, he found the parallaxes of 70 Ophiuchi, Lalande 2156 and O. Arg. 17415-6; he also surveyed the stars in the Cluster *h* Persei, and studied the orbit of the small planet Themis to determine the mass of Jupiter.

The value obtained was intermediate between those found by Airy and Bessel for the same quantity, and was greater, by its 58/1,000,000 part, than the then generally accepted value.

In 1880 Dr. Krueger was chosen Director of the Kiel Observatory succeeding Dr. C. A. F. Peters whose death caused the vacancy. He soon became also editor of the *Astronomische Nachrichten* which from its hundredth volume was pub-

lished under the direction of the Astronomische Gesellschaft, although undoubtedly Dr. Krueger had quite independent control. The success of this leading astronomical publication for the last sixteen years has been due entirely to him.

Though proposed by Dr. Förster, the central station for astronomical telegrams was sometime ago put under the charge of Dr. Krueger who discharged its duties faithfully and very successfully. Before leaving Bonn, Dr. Krueger married the daughter of Argelander, and following the good example, it happened later that the daughter of Dr. Krueger was married to Dr. Kreutz, astronomer now at Keil and temporarily in charge of the *Astronomische Nachrichten*. Most of the above facts are taken from the *Observatory*.

A Correction.—I have but just now seen my copy of POPULAR ASTRONOMY for June, 1896, and hasten to make a correction in reference to two of the photographs of nebulæ that appear in Mr. Clark's important article on the Life-History of Star Systems.

The beautiful photograph of the Whirlpool Nebulæ and the one of the Annular Nebula of Lyra are the work of Dr. Isaac Roberts with his 20-inch reflector, and are improperly credited to me. E. E. BARNARD.

Chicago, 1896, June 17.

Stars in the Skies of India.—Miss Mary Etta Moulton, graduate of Carleton College, Class of '94, now missionary in India, located at Bombay and vicinity writes instructively about the appearance of the stars in the skies of that more southern latitude. The high path of Mercury and the long time the planet is in view, when favorably situated, contrasted greatly with the infrequent and scanty views of more northern latitudes. Miss Moulton is planning for some small instruments for observations in recreation hours. We hope she may soon have them.

Organization of the Yerkes Observatory.—The organization of the Yerkes Observatory, University of Chicago, was recently announced by bulletin prepared by its Director, Professor George E. Hale. The personnel of the organization is as follows:

George E. Hale, Director; S. W. Burnham, Astronomer; E. E. Barnard, Astronomer; F. L. O Wadsworth, Astrophysicist; T. J. J. See, Instructor at the University; Kurt Laves, Assistant at the University; Ferdinand Ellerman, Assistant; G. Willis Ritchey, Optician; Edmund Kandler, Mechanician; William Gaertner, Mechanician.

The Yerkes Observatory was founded in 1892 through the munificence of Mr. Charles T. Yerkes, of Chicago. In that year Mr. Alvan G. Clark undertook the construction of an object-glass of forty inches aperture for the principal telescope of the Observatory, and Messrs. Warner & Swasey were given a contract for the equatorial mounting. The latter was completed in the following year, and exhibited by its makers at the Columbian Exposition. It is similar to the mounting of the 36-inch Lick telescope, but is heavier and more rigid, and many improvements have been introduced. An important feature, long ago suggested by Grubb and others, but apparently employed for the first time in this telescope, is a system of electric motors, by means of which the various motions, etc., are affected. The object-glass has recently been tested by Professor James E. Keeler, who acted at the request of the Director as the "expert agent" called for by the contract. The definition was found to be fully equal to that of the Lick telescope, while the light-gathering power is considerably greater.

The attachments of the Yerkes telescope will include:

1. A position micrometer by Warner & Swasey.

2. A solar spectrograph, for micrometrical and photographic investigations of the spectra of solar phenomena.

3. A spectroheliograph, for photographing the solar chromosphere, prominences and faculæ by monochromatic light.

4. A stellar spectrograph for researches on the spectra and motions of stars, nebulæ, comets and planets.

5. A photoheliograph of great focal length, for photographing the direct solar image on a large scale.

The construction of the main building was begun in April, 1895. After many delays it is now under roof, and will be completed during this summer. Its form is that of a Roman cross, with three domes and a meridian room at the extremities. The principal axis of the building (about 330 feet long) lies east and west with the dome for the 40-inch telescope at the western end. This dome is made by Messrs. Warner & Swasey, and is 90 feet in diameter, allowing ample space for the tube of the great telescope, which with its attachments, is about 75 feet long. The elevating floor of the observing room is 75 feet in diameter, and will be movable through a range of 22 feet, by means of electric motors.

Of the two smaller domes, the one to the northwest will contain the 12-inch telescope now at the Kenwood Observatory, and the other a 24-inch reflector. Between these domes is the heliostat room, 160 feet long and 12 feet wide. A heliostat with 24-inch plane mirror will stand on a pier at the north end of the room, under an iron roof which can be rolled away to the south.

The meridian room has double sheet-iron walls, with an intervening air space. It is designed to contain a meridian circle of large aperture, but for the present a transit instrument will suffice for the purposes of the Observatory.

The body of the building is divided through the center by a hall-way extending from the meridian room to the great tower. On either side are offices and computing rooms, a library, lecture room, two spectroscopic laboratories, dark room, developing room, galvanometer room, chemical laboratory, instrument rooms, etc. In the basement is a large photographic dark room, an enlarging room, concave grating room with large concave grating spectroscope, emulsion room, constant-temperature room, physical laboratory and optician's room. The engines, dynamos and boilers for supplying power and heat are to be at a distance of several hundred feet from the Observatory.

When the building is completed a cut of it will be given in this publication, and further description with it to enable readers to gain a complete idea of the plan and instruments of one of the greatest observatories in the world.

Its location is on Williams Bay, Lake Geneva, Wisconsin.

Temperature of the Sun.—Professor Paschen has been making a study of the temperature of the Sun on the supposition that the wave-length of the radiation of maximum energy in sunlight is inversely proportionate to the absolute temperature of an incandescent body. This method works out a solar temperature of 5,130° Centigrade or 9,266° Fahrenheit; Rosetti's value was 10,000° C. by aid of thermopile; Le Chatelier, 7,600° C. by comparative absorption of solar rays with rays from a hot object; Wilson and Gray, 6,200° C., by comparing radiation from the Sun with a glowing strip of platinum in a Boys radiometer; and Scheiner between 4,000° C. and 10,000° C. by measuring the breadth of the magnesium lines in the spectrum.

ERRATA:—(1). p. 503, 14th line from top, read "*other* system-type," instead of "*solar* system-type."

(2). p. 503, Figure VII, read, "a = Circle," instead of "a = Circles."

(3). p. 505, 6th line from top, read, "*causal* side," instead of "*casual* side."

(4). p. 512, 17th line from bottom, read, "*to* inspire," instead of "*of* inspire."

ERRATA.—In the May number, page 401, line 5, for "1896," read "1895."